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THE ENGINEER CENTENARY NUMBER

On January 4th next we shall publish a special Centenary Number, extra to our normal weekly issues, in celebration of the completion of 100 years of continuous publication of this journal since the first issue appeared on January 4th, 1856. It is our wish that every postal subscriber and regular reader of THE ENGINEER shall receive a free copy of this Number. Postal Subscribers will each be sent one copy of the Number by post.

TO REGULAR READERS WHO BUY THEIR COPIES FROM NEWSAGENTS

Free copies of the Centenary Number are not being distributed through newsagents. Your free copy can only be sent to you if you return to us the reply-paid postcard which was part of an inset facing page 786 of our December 2nd issue.

Please return this postcard now if you have not already done so.

BRITISH MACHINE TOOL INDUSTRY

The machine tool industry of this country is almost constantly under criticism. For it does not produce—and for a great many years never has produced—all the varieties of tools that are needed by British industry. In consequence, from time to time, it is publicly castigated for conservatism and unwillingness to develop new lines and for its backwardness relative to the machine tool industries of other nations. In addition, it sometimes has to suffer the criticisms, particularly when demand is high, that it lacks courage to expand its output, or, whenever a change like the coming of carbide-tipped tools or the advent of electronic control devices occurs, that it does not adapt its designs quickly enough to take advantage of the new situation. A survey of the British machine tool industry recently issued by the Noble Lowndes Finance Company, Ltd., presents a more balanced view. It does, indeed, point out that the bulk of technical development in this country is being carried out by relatively few manufacturers who are willing to undertake expensive research and development work, returns upon which are not likely to be evident for some considerable time. That, of course, in an industry in which small firms predominate, is rather natural. It states that American makers have a lead technically in the design of mass production tools—the British machine tool industry would, we think, agree—and it considers that German manufacturers are ahead of the British in the production of certain kinds of tool—it can hardly be denied—and are particularly adept at modifying tools to customers' requirements. But these facts cannot be taken to indicate that the British industry is not in a healthy state. No industry with orders on hand to the value of £88,000,000—equivalent to at least fifteen months' output—order books, after a slack period, now again filling up, and a high, healthy and growing demand from abroad (amounting to about 25 per cent of total orders) can really be held to be producing goods not of standards comparable with those of other nations.

But criticism of the British machine tool industry is directed far less against the quality of the tools it does make than against the tools it does not make! It is accepted that the industry is second to none for the production of a wide range of standard machines used in all branches of engineering and that for many years past it has been occupied in developing and producing these machines profitably for home and overseas markets. It is recognised that the standard machines will always be needed in large numbers, particularly by the multiplicity of firms engaged in individual component or small batch production, and that the majority of these machines now incorporate in their designs developments to give economic, high-speed, precision production based upon the most modern practice, but without expensive and often little used "frills." The manufacture of such tools is, and must remain for many years to come, the bread and butter of machine tool makers, and no one would deny

that the demand for such tools must be met even if in consequence relatively small demands for tools of other kinds has to be met by imports from abroad. But is it safe to concentrate so fully on bread and butter lines, lacking the stimulation to new thought that a constant development of new designs brings with it ? There the critic fails to recognise that the maker of machine tools is not wholly his own master.' It is not worth while manufacturing machines of specially advanced design, however well they may seem adapted to the needs of industry, unless users can be convinced that such machines will be profitable to buy in sufficient quantity. Not all the criticisms of conservatism and complacency directed at the British machine tool industry are levelled at the real culprit. It is sometimes the user who is at fault. It is, of course, true that if by its own folly or that of users the British machine tool industry concentrated too much upon standard lines it might fall into a comatose and complacent state, content to let other nations lead. That seems to be what the critics fear. But is it happening ? We confidently expect that next year's Machine Tool Exhibition will show that it is not.

It may well be that there is still insufficient realisation in the machine tool industry generally of the light that a more scientific approach could throw on machine tool design, as the papers read and discussed at the Institution of Mechanical Engineers last Friday indicated. There might well be, for example, more appreciation and understanding within the industry of the work of the Production Engineering Research Association. But that is a kind of criticism that can be levelled at several other industries besides that of machine tool production. Statistics, for example, of the proportions of university graduates on the staffs of manufacturing firms reveal startling differences as between one industry and another, differences so startling that one is led to question whether adverse criticism of those with few is really warranted. But it does seem necessary that the number of scientifically trained people in the machine tool industry (perhaps on the machine shop floor in other industries, too) should increase. The repercussions of the advent of automation on the machine tool industry have recently been too highly stressed. Automation, except in a relatively small section of industry at present engaged in mass production, is still a long way off. But unless this country is eventually to rely on imports for a large percentage of high-production, special-purpose machines and those incorporating programme control, attention needs to be given now to their design so that future demands can be met. Their design, certainly on the electronic side and very probably on the mechanical as well, will call for a more scientific approach than has so far been essential. But we have no evidence that the British machine tool industry is unaware of the situation—rather the reverse. It would be folly, indeed, for it to ignore trends that were obviously in evidence at recent Continental and American exhibitions.

THE EMBANKMENT PROPOSAL

Every journal, whatever its character, is obviously pleased to find a subject that attracts particular attention to its pages and the *Evening News* plan for a high-speed highway to parallel London's Embankment between Chelsea and the City, built out upon "stilts" over the River Thames, is anything but sheer sensationalism. Little study of it is needed to show that it is a practicable proposal. The proposal has also in its favour the virtue that it would be relatively very cheap to construct as compared with any other alternative. But because something is both practicable and cheap it does not mean that it ought to be built. The project has not so far been at all completely studied in relation to London's traffic needs as a whole. Nor can it be considered in isolation from other factors such as river-side amenities and parking space in the City. Moreover, several arguments prejudicial to the scheme leap to the mind. One is architectural. Do we want, even if only in appearance, to make the Thames seem any narrower than it is at present? Another is that the present Embankment roadway for the greater part of its length is amply wide enough to carry a much greater weight of traffic than at present. It is the crossings that hold up the traffic flow. Is it necessary to build a new structure over the river all the way from Chelsea to the City in order to eliminate some of those crossings ? Furthermore, the point can be made that to some extent the cheapness of construction cost is illusory. For to serve a real purpose the new road would have to be extended East and West to link up with arterial highways. If so extended would the new road prove to be well sited to serve traffic needs for eastward and westward flow, and does eastward and westward flow demand priority over northward and southward flow ? We confess to a lack of conviction that in these senses a new Embankment road would prove a better answer to London's traffic problems than others that have been proposed.

Care, however, in assessing the merits of the scheme, is needed to ensure that like is compared with like. If, as we assume, the project is intended to form part of a great high-speed road traversing London from east to west then it cannot logically be argued that there is a prior need to carry out such schemes as the removal of the Notting Hill Gate bottleneck or the improvement at Hyde Park Corner. Like would not be compared with like. To argue in such a way would be analogous to suggesting that the elimination of accident black spots on Britain's main roads should have priority over the building of motor-ways ! In fact, distinct and separate problems are involved. One of them is that of removing restrictions which prevent existing streets being used to full capacity ; the others, which the *Evening News* plan seems in part to be designed to meet, are those of providing new access to the centre of London from outside, and of diverting through traffic away from existing heavily congested streets. Where priorities are involved it is with other schemes of a like character that the *Evening News* project needs to be compared. Unfortunately, however, there is very little ground on which to make the comparison. For the project seems to have been formulated without any serious attempt to estimate how much traffic could be expected to flow along the new route or how much relief would be afforded to other streets. But the fact that no full appreciation of the structure's possibilities has been made does not mean that publication of the plan is untimely. The great virtue of the plan and of the manner in which the *Evening News* has presented it is that it draws the attention not merely of road and traffic engineers to one of London's urgent needs but that of the travelling public too. To get traffic into and out of London and other large cities demands in this country, as it has in the United States, the building of motorways from the outskirts into the centre. But so long as control of road expenditure lies in the hands of the Government the necessarily high capital cost will not be faced unless the public demands it, even though conservative estimates of the savings accruing justify the proposals economically.

The *Evening News* plan also emphasises another problem in fitting old cities for modern traffic. If the new Embankment road were built or any other arterial road extended into London its effect would undoubtedly be to increase the daily flow of cars and commercial traffic. At present it is congestion, and congestion alone, that restrains many more people from using their cars for travelling to and from London. Improved access would encourage the growth of such traffic. The necessary corollary to the building of new roads is, therefore, the provision of more adequate parking and garaging space. Necessarily the high cost of building roads and constructing garages will be challenged. Is there no cheaper way ? We doubt it. A free flow of commercial, business and passenger traffic into and out of London is essential to its well-being. Only the construction at great expense of new access roads on an American scale promises to give relief.

A Seven Day Journal

Reorganisation of Administration on the Eastern Region of British Railways

IT has been announced that the Eastern Area Board of the British Transport Commission has approved the first steps towards a change in organisation which will lead to a major devolution of authority and responsibility throughout the traffic departments of the Eastern Region of British Railways. The scheme will also serve to bring the work of the operating and commercial departments closer together. Under the plan the separate posts of chief commercial manager and chief operating superintendent are to be abolished and the functions of their departments and other departments concerned with traffic at the headquarters of the Region will be redefined and placed under an assistant general manager (traffic) at the headquarters. Away from headquarters the district responsibilities of the operating, motive power and commercial departments will be controlled by a traffic manager for each convenient line or area. These traffic managers will have greater authority than is at present delegated to local officers and they will be directly responsible to the assistant general manager (traffic). As a result of this delegation of authority it is expected that the amount of reference to headquarters on departmental matters will be greatly reduced and the administrative burden now falling on the general management will be greatly lightened. At the same time it is expected that control by a single traffic manager of the principal functions directly concerning the public and traffic working will lead to a considerable improvement in the flexibility and individuality of the railway service. In connection with these changes the appointment of Mr. H. C. Johnson as assistant general manager (traffic) has already been announced. It is of interest to note that there are 2842 route miles of railway in the Eastern Region which serves 1105 stations and has 58 motive power depots and 139 marshalling yards.

Central Electricity Authority

WE learn that Mr. J. D. Peattie, deputy chief engineer (generation) of the Central Electricity Authority, has been appointed acting chief engineer of the Authority and will take over the duties of Mr. V. A. Pask, who, as previously announced, will retire at the end of this year. Mr. Peattie, who was educated at Morgan Academy, Dundee, St. Andrews University and London University, began his career in engineering by spending three years in Berlin, where he was engaged on high-voltage d.c. research with Siemens-Schuckertwerke. During the first world war he served with the Royal Naval Division and the Royal Engineers. Afterwards, he gained experience in heavy plant, factory and mains installations, first with Metropolitan-Vickers Electrical Company, Ltd., and then with Edmiston Brown, of Glasgow. His association with the electricity supply industry began in 1928, when he joined the Manchester Corporation Electricity Department, and was responsible for the change-over from d.c. to a.c. of the low-voltage distribution system. He first became concerned with the grid system in 1929, when he was appointed operation engineer, headquarters, of the Central Electricity Board. In 1944 he became deputy chief engineer of the C.E.B., and with the Central Electricity Authority he has held the position of deputy chief engineer for transmission (1947/49) and for generation from 1949 up to the present. Mr. Peattie has been responsible for much pioneering work in the development of the national grid system, notably with the forward planning of extensions to the country's generating capacity, and with the control of the output from all public stations and of the interconnecting grid.

The Engineers' Guild

THE annual general meeting of the Engineers' Guild was held in London on Wednesday of last week. Mr. Bryan Donkin was elected president for a second year, and Mr. J. G. Orr was appointed secretary. The report of the general council, for the year ended September 30th last, records a membership of 4449, compared with 4228 a year earlier. The report says that although the number of new elections has been less than in the preceding year the rate of recruitment continues to be "reasonably satisfactory" and approximately 1900 members and associates have joined the Guild during the past three years. At the same time, the council is concerned at the continuing resignations and deletions from the register, although, the report adds, "the number of those whose subscriptions are in arrears has shown a welcome decrease and is now the lowest for many years." Another matter mentioned in the council's report is the attention given during the past year to the need for securing effective representation of the professional engineer, particularly in those fields in which joint negotiating machinery has been established.

Monopolies Commission's Report on Pneumatic Tyres

AT the end of last week, the report of the Monopolies and Restrictive Practices Commission on the supply and export of pneumatic tyres was published by H. M. Stationery Office. There are twenty-two conclusions and recommendations presented in the report all but two of which represent the unanimous view of the chairman and eight members of the Commission who have signed the report. The first of the conclusions is that the discussions on prices which take place within the Tyre Manufacturers' Conference strengthen the tendency inherent in the structure of the industry to reduce price competition and are against the public interest. The recommendation about this is that the Tyre Manufacturers' Conference should no longer concern itself with the question of price levels and price changes and that no other committee or organisation should be set up or employed for the purpose by the tyre manufacturers. Then, there is the observation that the system under which identical prices to the consumer are collectively maintained is against the public interest. The majority view of the Commission is that the only way to secure genuine price competition at the retail stage is to abolish the maintenance of retail prices, and it is recommended that "no manufacturer should prescribe the retail price of his tyres." Another conclusion is that the maintenance by the Tyre Trade Joint Committee of the tyre trade register and, by the Tyre Manufacturers' Conference, of the agricultural and earth-mover tyre trade register, the aircraft tyre trade register and the aircraft constructors register tends to create a privileged class of trader and is against the public interest. It is recommended that these registers should be discontinued. It is also stated in the report that the supplemental agreement of the Society of Motor Manufacturers and Traders, requiring tyre makers to prohibit traders from exhibiting loose tyres at shows not approved under the Society's bond, interferes with the legitimate interests of traders. In this way, the report says, it is against the public interest and should be terminated.

Gas Turbine Development

AT the Institution of Civil Engineers on Tuesday last, the Parsons Memorial Lecture was read by Sir Harold Roxbee Cox, describing it as his last lecture on the subject of gas turbines. He traced the early history from the schemes of Barber, featuring water injection and visualising jet propulsion, to the flights of Heinkel, Gloster and Bell turbo-jet aircraft. The various forms of aircraft turbine, ranging from tip-jet rotors to by-pass engines, and the application of the shaft-power turbine in ships, cars, and various locomotives were described. The development of gas turbine generating stations was traced from its beginnings at Neuchatel to the trials of the Parsons installation at Dunston. The lecturer next discussed the problems facing the gas turbine at present, particularly the difficulty of burning low-grade fuels such as residual oil. He went on to predict the employment of "this Proteus of engines" for utilising the heat generated in nuclear reactors, and illustrated a projected 15,000 h.p. marine propulsion set with liquid metal cooling of the reactor, an intermediate stage of heat exchange to another liquid metal circuit, and helium as the working fluid of the cycle: this plant was expected to avoid a prohibitive level of radioactivity in the prime mover. Sir Harold concluded by referring to the influence of the work of Sir Charles Parsons on steam turbines and axial compressors upon the internal combustion engine.

Accidents in Coal Mines

THE latest annual report of H.M. Chief Inspector of Mines, which has been published this week, is that which covers the year 1953. In that year, it is stated, there were 1632 mines at work under the Coal Mines Act, 1911, of which 1473 were producing coal. During the year H.M. Inspectors of Mines made 17,496 underground and 8628 surface inspections. The Chief Inspector says that he is glad to be able to report that both the number of persons killed and the total of those killed and seriously injured in coal mining were lower than in any previous year of full employment. Accidents in 1953 caused 392 deaths, or twenty-eight fewer than in the preceding year, and there were 1958 people injured in "immediately reportable" accidents, which was 151 less than in 1952. The number of people disabled by mine accidents for more than three days declined from 238,100 in 1952 to 234,000 in 1953, and the observation made by the report is that "it is to be hoped that the peak has now been passed." The Chief Inspector believes that the reduction, in 1953, in the number of mining casualties was not simply attributable to a fall in the level of employment and production during the year. Indeed, the report says, the number of persons employed actually increased, and, while coal output fell by less than 1 per cent and the number of manshifts worked by 2 per cent, the number of accidents fell by 7 per cent.

Effects of Indicator Passages on the Accuracy of Indicator Diagrams

By J. G. WITHERS, B.Sc., M.I.Mech.E.

In many engines, particularly those of small cylinder size, it is impossible, or at least very difficult, to arrange for the pressure sensitive element of an indicator to be flush with the combustion chamber surface. Unfortunately, however, with the smallest engines, which run at the highest speeds, the error resulting from an indicator passage is greatest. The effects of indicator passages on the accuracy of indicator diagrams have been studied first to find the limits in length which give a negligible error and secondly to obtain an indication of the magnitude of error resulting from longer passages in applications where it is impossible to keep within the recommended limits. Indicator passages are examined in relation to their effects on the following aspects of indicator diagrams : compression ratio, indicated mean effective pressure, maximum pressure, resonance, maximum rate of pressure rise, detonation, and sudden changes in the contour ; and data are given which enable the influence of an indicator passage to be estimated quantitatively. Faults in the design of indicator passages are discussed and methods are given of applying passages to difficult cases.

IN the early days the only instruments available for obtaining the indicator diagrams of internal combustion engines were of the mechanical piston type, which were severely limited in maximum speed of operation. In consequence, little attention was paid to the effects of any communicating passage between the combustion space and the piston of the indicator, because at the most the passage caused an error which was then only of second order importance. The introduction of cathode-ray oscillograph indicators[1,2,3,4] which, as far as reciprocating engines are concerned, are practically unlimited in speed of operation, has focused attention on the importance of the indicator passage because increase in speed is likely to increase the errors associated with the passage ; and with many small high-speed engines it is quite impossible to arrange for the pressure sensitive element to be flush with the surface of the combustion space.

Early thoughts on the subject were that the whole of the indicated pressure diagram would lag behind the pressure in the cylinder by an amount equivalent to the time taken for sound waves to travel the length of the passage. On this basis a diesel engine operating at 1800 r.p.m., with an indicator passage of, say, 1½in in length, would give a lag of about 1 crankshaft degree. This, at first sight, seems small enough ; but, unfortunately, the area of the indicated pressure-volume diagram or apparent indicated mean effective pressure is extremely sensitive to small changes in angular phasing in relation to piston position. A lag results in an exaggeration of the true work area ; and Stansfield and Withers[5] have shown that the error introduced in the work area for one crankshaft degree error in phasing is empirically expressed as follows :—

$$\text{Per cent error in indicated mean effective pressure} = \frac{\text{compression pressure} + \text{maximum pressure}}{2 \times \text{i.m.e.p.}} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Thus the absolute error in the indicated mean effective pressure

$$= \frac{\text{compression pressure} + \text{maximum pressure}}{200} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

For a diesel engine with compression and maximum pressure 500 lb and 1000 lb per square inch, respectively, the error in indicated mean effective pressure is, therefore 7½ lb per square inch. This is important enough at full load, but becomes even more important as the load is reduced ; it shows that extreme care is necessary in setting the phasing of the indicator, and suggests that errors introduced by the indicator passage may be quite large. The application of a correction for the indicator passage in the form of a uniform angular correction to the indicator diagram as a whole, while comparatively easy to carry out, is clearly unsound because the passage is a resonant system undergoing complex forced vibrations with damping, and each harmonic component of the indicator diagram will have a different lag.

Using the classical theory for the propagation of acoustical waves, in which it is assumed that the pressure amplitude is infinitely small in comparison with the mean pressure, the following expressions can be developed for damped oscillations in a tube closed at one end :—

$$\text{Amplitude ratio} = \sqrt{\frac{2}{\cosh 2al + \cos 2bl}} \quad . \quad (3)$$

$$\text{Phase lag} = \tan^{-1}(\tanh al \,.\, \tan bl) \quad . \quad (4)$$

Where a = damping factor/unit length.
l = length of tube.
$b = \frac{2\pi n}{c}$.
n = frequency of component.
c = velocity of sound.

In order to use these expressions the indicator diagram on a time base must first be broken up into a series of sine waves of integral multiples of the engine speed by means of harmonic analysis. This is a straightforward, though tedious process, from which the amplitudes as well as the phase relations of the components can be obtained.

The contribution of individual harmonic components towards the indicated mean effective pressure can be determined from :

(*a*) The general expression for a pressure component :

$$y = A_n \cos(n\theta + \phi)$$

where : A_n is the amplitude of the nth order harmonic component.

n is the harmonic order.
θ is the crank angle.
ϕ is the phase relationship of the component,

and (*b*) The expression for piston displacement :

$$x = 1 - \cos\theta + \frac{1}{2R}\sin^2\theta$$

where R = connecting rod length/crank radius.

The resulting expression for indicated mean effective pressure is approximately as follows :—

$$\text{I.M.E.P.} = \pi\left(\frac{A_1}{2}\sin\phi_1 + \frac{A_2}{4R}\sin\phi_2\right) \quad . \quad (5)$$

Thus, only the first two terms in the harmonic analysis have any appreciable influence on indicated mean effective pressure ; this is quite important as it means that only relatively low frequencies need be considered.

An examination of the harmonic components from a series of passages of different length makes possible the calculation of the damping factor. This has been done by the author for typical diesel engine diagrams ; but unfortunately the damping factor obtained from the phase angle formula was found to be several times as large as that obtained from amplitude attenuation. The reason is probably associated with the large amplitude of the pressure components of the indicator diagram which cannot by any stretch of imagination be considered to satisfy the basic assumption for acoustical vibrations, that the amplitude is small in comparison with the mean pressure. An alternative approach was made by relaxation methods, which could deal with large pressure amplitudes, but the energy loss due to damping could not easily be allowed for. A further complication is that the damping factor for vibrations in a passage is likely to increase with frequency. This is certainly true for sound waves ; Rayleigh[6] has shown that the damping factor increases as the square root of the frequency, and the author's experiments on the phase changes of harmonic components of indicator diagrams showed that the square root frequency relationship was approximately true.

The difficulty in obtaining a rigid general treatment for large amplitude vibrations in a small tube, and the complicated procedure that would be necessary to apply a solution, even if it were found, led the author to abandon the analytical approach in favour of entirely experimental methods. In these the effects of indicator passages on the important aspects of indicator diagrams are examined separately, using the Standard-Sunbury Engine Indicator Type F.[4]

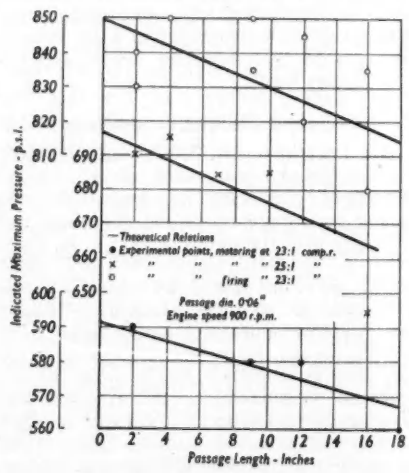

Fig. 1—Effect of an indicator passage on compression pressure by reduction of compression ratio

Reduction of Compression Ratio

It does not follow that a small diameter pipe connected to the cylinder will necessarily add its total volume to the effective clearance volume. In order to measure the influence of an indicator passage on the effective

clearance volume, a variable compression ratio diesel engine of 3½in bore and 4½in stroke was used. A Y-piece connector was fitted to the engine cylinder such that a pickup unit could be screwed into one leg and variable lengths of 0·06in internal diameter pipe, with the end remote from the engine blanked off, fitted to the other leg. Maximum pressure readings for various passage lengths were then obtained at different compression ratios under motoring and firing conditions. The results obtained are shown in Fig. 1, which also gives the calculated pressure reductions assuming the passage volume adds to the clearance volume, for comparison with the experimental results. Because of varying leakage in the system used for altering the compression ratio the deviations of individual points from the calculated lines are considerable; but particularly under firing conditions, there seems good reason to believe that the whole of the indicator passage volume is effective as clearance volume. It is important therefore that the passage volume shall be small in relation to the clearance volume, but normally with fairly short passages of the bore size considered this presents no difficulty.

Indicated Mean Effective Pressure

In order to examine the effect of an indicator passage on indicated mean effective pressure it is necessary to have a reproducible indicator diagram. For this purpose an engine of 2½in bore and 3½in stroke was used; it was motored, as when firing there is a greater variability from cycle to cycle. The compression maximum pressure was about 165 lb per square inch. Cylinder pressure diagrams were taken with

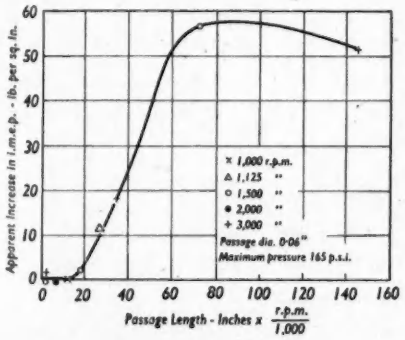
Apparent Increase in i.m.e.p. - lb. per sq. in.
Passage Length - Inches x r.p.m./1,000
× 1,000 r.p.m.
△ 1,125 "
○ 1,500 "
• 2,000 "
+ 3,000 "
Passage dia. 0·06"
Maximum pressure 165 p.s.i.

Fig. 2—Effect of an indicator passage and r.p.m. on errors in i.m.e.p.

the Standard-Sunbury calibrating unit at various motoring speeds for indicator passages of length 0·75in, 12in, 24in and 48in. The passage diameter was 0·06in, which is the value used with the Standard-Sunbury indicator for calibrated diagrams. Pressure displacement work area diagrams were then plotted.

When an engine is motored, apart from pumping losses in the suction and exhaust strokes substantially no work is done in the cylinder as the small amount due to irreversibility of the cycle can usually be neglected. With no indicator passage, there should therefore be little or no work area enclosed between the compression and expansion strokes, and zero or a very low mean effective pressure should be recorded. Any appreciable apparent work area obtained when using indicator passages must, therefore, be caused by the passages. In Fig. 2 the mean effective pressures calculated from the diagrams have been plotted against the product of passage length in inches and r.p.m./1000, referred to later as the passage factor. The results for the different speeds form a common curve; and further the mean pressure is zero until the passage factor reaches a limiting value of twelve. Quite long passages can therefore be used without error in indicated mean effective pressure.

Maximum Pressure

The maximum pressures from the indicator diagrams previously referred to have been plotted in the same way as the corresponding indicated mean effective pressure values, and

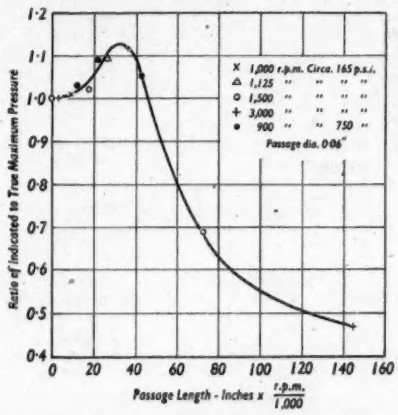
Ratio of Indicated to True Maximum Pressure
Passage Length - Inches x r.p.m./1,000
× 1,000 r.p.m. Circa. 165 p.s.i.
△ 1,125 " " " "
○ 1,500 " " " "
+ 3,000 " " " "
• 900 " " 750 "
Passage dia. 0·06"

Fig. 3—Effect of an indicator passage and r.p.m. on indicated maximum pressure

are shown in Fig. 3. At a passage factor of twelve, which gave correct indication of indicated mean effective pressure, the error in maximum pressure is about 2 per cent; maximum pressure therefore may be somewhat more limiting with regard to indicator passage length than indicated mean effective pressure. Again, however, the product of passage length and engine speed is a satisfactory parameter for assessing indicator passage errors.

The data so far discussed relate to maximum pressures of approximately 165 lb per square inch. Additional tests were made on the variable compression diesel engine, which could give a motored maximum compression pressure of approximately 750 lb per square inch, and the results are included in Fig. 3; these agree closely with the values obtained at the lower pressure. Since the level of maximum pressure does not affect the point at which errors in maximum pressure are introduced, it is unlikely that increased maximum pressure will affect

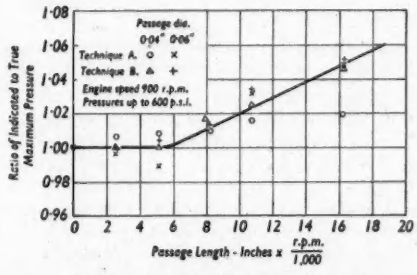
Ratio of Indicated to True Maximum Pressure
Passage Length - Inches x r.p.m./1,000
Passage dia. 0·04" 0·06"
Technique A. ○ ×
Technique B. △ +
Engine speed 900 r.p.m.
Pressures up to 600 p.s.i.

Fig. 4—Effect of an indicator passage on indicated maximum pressure

the point where errors in indicated mean effective pressure commence; Fig. 2 therefore can also be regarded as independent of the pressure level. A further series of tests was conducted in the variable compression diesel engine covering a lower more practical range of passage factors, and the results are given in Fig. 4. Technique A refers to tests similar to those in Fig. 3, in which a calibrating unit was fitted to the remote end of the passage and the readings corrected for the passage volume; technique B refers to tests in which there was an additional reference pickup at the engine end of the passage, obviating the need for a passage volume correction. The two techniques give within experimental error the same curve and confirm the results given in Fig. 3; the limiting passage factor for maximum pressure measurement is seen to be six. Fig. 4 also shows that the same curve applies to the 0·04in diameter passages, used in the Standard-Sunbury indicator diaphragm units, as well as for the 0·06in diameter passage used with calibrating units.

The data given in Figs. 3 and 4 are applicable only when the rate of pressure rise is insufficient to set the indicator passage into forced vibration. In such circumstances calibrated measurements of maximum pressure can have an additional error over and above that already discussed. This aspect will be discussed further in the next section.

Passage Resonance

When the rate of pressure rise is very high, as in diesel engines with long ignition delay accompanied by combustion knock, and in gasoline engines under detonating conditions, the indicator passage can be shock-excited into a damped vibration at its resonant frequency. In very severe circumstances the gases in the combustion chamber too can be set into vibration, but when vibrations on an indicator diagram are encountered the indicator passage should first be suspected. Indicator passage vibrations take the form of a superimposed ripple on the pressure diagram immediately following the point of maximum rate of pressure rise during com-

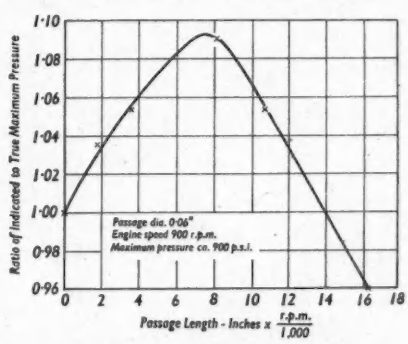
Ratio of Indicated to True Maximum Pressure
Passage Length - Inches x r.p.m./1,000
Passage dia. 0·06"
Engine speed 900 r.p.m.
Maximum pressure ca. 900 p.s.i.

Fig. 5—Effect of an indicator passage on maximum pressure with high rates of pressure rise

bustion, and are most noticeable in the region of maximum pressure; on the rate of pressure rise diagram they are even more apparent as amplification of components of an indicator diagram is then in direct proportion to the frequency.

With the pictorial diagrams obtained from diaphragm type units of the Standard-Sunbury indicator it is possible to avoid error in maximum pressure by taking the mean line through the superimposed ripple; but with the calibrating unit it is usually impossible to determine anything other than the highest pressure occurring at the end of the passage; this is because the period of the vibrations is usually short in comparison with the time taken for the calibrating unit disc valve to travel from one seat to the other. Whether the maximum pressure as indicated by the calibrating unit will be increased or reduced depends on the phasing of the vibration in relation to the maximum pressure point, but with fairly short passages exaggeration of maximum pressure is more likely. Fig. 5 shows the errors in maximum pressure obtained with the calibrating unit when operating the variable compression diesel

engine on a low cetane number fuel ; the maximum rate of pressure rise was then about 350 lb per square inch per millisecond. The technique used was that in which an additional reference pickup was located at the engine end of the passage. Magnifications of up to 9 per cent are shown for a 0·06in diameter passage at much lower passage factors than are given in Fig. 3 for lower rates of pressure rise.

A further study of the magnitude of resonant passage vibrations was made using passages of 0·04in and 0·06in diameter using the diesel engine under the same conditions as for Fig. 5, and using diaphragm type units to obtain pictorial indicator diagrams. No noticeable distortion of the diagrams was observed up to passage factors of 2 and 3 for the 0·06in and 0·04in diameter passages respectively. Where passage vibrations are troublesome the smaller passage diameter is to be preferred ; it is possible that a passage of 0·03in diameter might give still better results on account of a further increase in damping. Ultimately, however, reduction in passage diameter must result in serious attenuation of important harmonics of the indicator diagram. A further drawback of small diameter passages, particularly with diesel engines, is the possibility of their rapidly choking with carbon.

Maximum Rate of Pressure Rise

With the Standard-Sunbury indicator the rate of change of pressure diagram can be obtained on the screen of the oscillograph when using the electromagnetic diaphragm type units. In order to examine the effect of

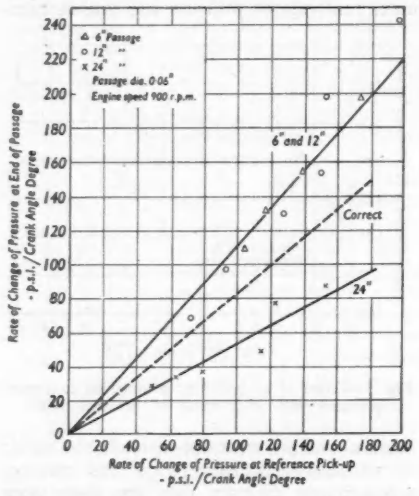
△ 6" Passage
○ 12" "
× 24" "
Passage dia. 0·06"
Engine speed 900 r.p.m.
6" and 12"
Correct
24"
Rate of Change of Pressure at End of Passage - p.s.i./Crank Angle Degree
Rate of Change of Pressure at Reference Pick-up - p.s.i./Crank Angle Degree

Fig. 6—Comparison between rate of change of pressure indicated at the end of a passage and at the cylinder

indicator passages the maximum rate of pressure rise during combustion was measured by pickup units at both ends of the passages. The variable compression diesel engine was used for this work and the injection timing, fuel ignition quality and compression ratio were varied to obtain a wide range of maximum rate of pressure rise ; in addition, the engine was motored to obtain low values. The results obtained are given in Figs. 6 and 7. An interesting and surprising feature is that for a given passage the indicated maximum rate of pressure rise values are a constant ratio of the true values, and the percentage errors are therefore independent of the value of the rate of pressure rise.

Fig. 8 shows the passage error obtained from the slopes of the lines in Figs. 6 and 7, in terms of passage length. A common curve has been drawn for the two passage diameters as the points do not indicate a different behaviour within the limits of experimental error. Large magnifications are shown for the short passages commonly used ; but the author considers that Fig. 8 gives

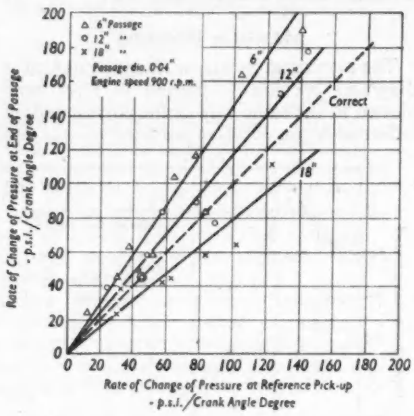
△ 6" Passage
○ 12" "
× 18" "
Passage dia. 0·04"
Engine speed 900 r.p.m.
6"
12"
Correct
18"
Rate of Change of Pressure at End of Passage - p.s.i./Crank Angle Degree
Rate of Change of Pressure at Reference Pick-up - p.s.i./Crank Angle Degree

Fig. 7—Comparison between rate of change of pressure indicated at the end of a passage and at the cylinder

a fair estimate of the extent of these exaggerations.

Detonation

Knock or detonation in a spark-ignition engine is believed to be caused by the auto-ignition of the end-gas together with sudden release of energy. It manifests itself as a local very rapid pressure rise followed by excitation of the major modes of vibration of the gas in the combustion space. The maximum rate of pressure rise, which is often used as a measure of knock intensity, can be measured subject to the errors detailed in the previous section, but the gaseous vibrations themselves can only be studied with the very shortest of indicator passages. The reason is that the damping with long passages is extremely high for these high

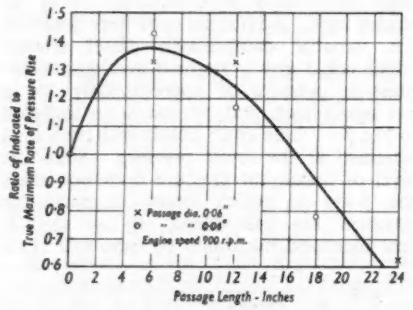

Fig. 8—Effect of an indicator passage on maximum rate of pressure rise

frequencies which are in the region of 2–10,000 c/s. With a passage length of ⅛in, which is about the shortest value for a screw-in type indicating unit, the resonant frequency of the passage is approximately 5500 c/s, and it is necessary for the damping to be critical to avoid over-amplification of detonation waves which are of similar frequency. The passage diameter of 0·04in used with the Standard-Sunbury indicator diaphragm type units is a fair compromise, but some beating between the two frequencies so close together is inevitable. A passage diameter of 0·03in reduces the beating, but may attenuate the detonation wave. If at all possible the pressure-sensitive element should be flush with the combustion chamber walls for this type of work.

Sudden Changes

It is often important to know the angular position of sudden changes in the contour of indicator diagrams, such as commencement of combustion, onset of detonation, point of maximum pressure, &c. Now the positions of these sudden changes are defined by the high order harmonic components of the indicator diagram whose damping may be very large indeed. If the damping factor is taken as infinity in expression (4) the phase lag is then given by :

$$bl = \frac{2\pi nl}{c}.$$

The time lag is, therefore, given by :—

$$t = \frac{l}{c}.$$

This is the same as is obtained from the direct calculation of the time for a sound wave to travel the length of the passage.

Confirmation of this view has been obtained by experiments on the effect of passage length on the indicated point of commencement of combustion in the diesel engine ; the results are given in Fig. 9, which shows that the lag increases linearly with passage length and, by calculation from the slope of the line, that the local velocity of sound is 1350ft per second. Tests on the indicated

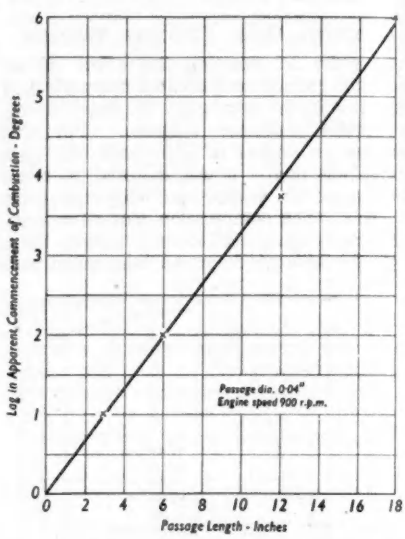

Fig. 9—Effect of passage length on angular lag

position of maximum pressure have shown a similar result. Thus, all sharp discontinuities will have a lag calculable from the local velocity of sound and the passage length. The estimation of the local velocity of sound requires a knowledge of the prevailing temperature, which is normally difficult to ascertain ; however, no serious error will be made if a velocity of sound of, say, 1350ft per second, as given by the line in Fig. 9, is assumed.

Design Details

While there is no doubt that it is always desirable to keep indicator passages as short as possible, in many practical applications it is impossible to avoid a passage because of space limitations in the engine cylinder head. In fact, in most high-speed motor vehicle engines the only way of communicating with the combustion space is by drilling through the cylinder, or cylinder head, flange. This will usually necessitate a passage length of at least 1in. It is unfortunate that high-speed engines, which most need short passages, present the greatest difficulty in obtaining them.

The arrangement shown in Fig. 10 is recommended for engines in which special indicator tappings are not available. It is important, though, in this, as in all other

indicating adaptations, that there is no increase in diameter from the combustion chamber to the indicating unit, apart from the air cell immediately under the indicator diaphragm. Local increases, which can be caused by badly fitting gaskets or badly designed adaptors, are particularly to be avoided. If there is to be any change in the passage section it must increase at each change from the indicating unit to the combustion space.

Condensed water or oil in small diameter indicator passages can cause large errors if the amount is sufficient to fill the passage at any point. Water or oil can also upset the functioning of indicator units by introducing heavy damping of the very small movements of the pressure-sensitive elements. It is, therefore, important in designing the layout of an indicator passage to take all possible

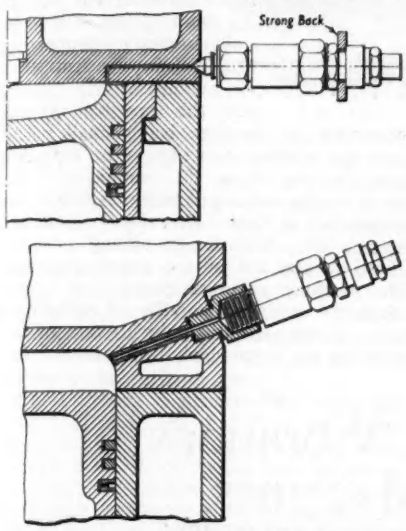

Fig. 10—Pick-up unit adaptors and indicator passages

precautions to prevent the presence of oil or water in the passage. Sometimes there are difficulties in drilling the necessary small diameter holes for indicator passages ; it is then usually possible to fit an inserted section of diesel engine high-pressure fuel tubing of the correct internal diameter, as shown in the lower diagram of Fig. 10.

Conclusions

The experimental work described has shown that, with a satisfactory passage layout designed along the lines suggested, accurate results can be obtained using much longer passages than hitherto thought possible. The passage length and diameter must be such that the volume added does not seriously affect the compression ratio. For correct indication of indicated mean effective pressure the product of passage length in inches and engine revolutions per minute divided by 1000 must not exceed twelve. Correct indication of maximum pressure at normal rates of pressure rise is given if the product of the passage length in inches and the engine revolutions per minute divided by 1000 does not exceed six. Passage resonance at high rates of pressure rise can seriously affect the indication of maximum pressure, and the shortest length of the smallest permissible passage diameter should be used when passage resonance is likely. Rates of pressure rise are over-estimated with the short passages in common use. Detonation waves can be studied only if the indicator pressure-sensitive element is flush with the combustion chamber surface, or if the shortest possible passage length, say, not exceeding $\frac{1}{4}$in, is used ; the passage diameter must not exceed 0·04in to obtain a satisfactory compromise between accurate indication of the detonation waves and the avoidance of unwanted beating with resonant vibrations of the passage ; a passage diameter of 0·03in may give the best result. The indication of sharp disturbances in the diagram, such as commencement of combustion, is delayed by an amount determined by the local velocity of sound and the passage length.

Using the above recommendations, it is believed that accurate pressure indicating is possible even in difficult circumstances ; and that, where corrections are necessary, they are not difficult to apply. The experimental work has been carried out using the Standard-Sunbury indicator, but the conclusions are applicable to all types of indicator.

Acknowledgments

The author wishes to thank Messrs. R. W. Hathaway and H. J. Hulf for carrying out the experimental work, and the chairman of The British Petroleum Company, Ltd., for permission to publish this article, which has resulted from work carried out at the Sunbury Research Station.

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Further Notes on the Development of Fairground Machinery

By P. W. BRADLEY

IT may be recalled that in the penultimate part of the series of articles on fairground machinery published in The Engineer in July-September, 1954, mention was made of the first known fairground usage of the hydraulic coupling method of speed control, in connection with a device known as "The Rotor," of Continental origin.

Since the articles were prepared, another established mechanical engineering principle —the use of compressed air as a working fluid for the transmission of energy—has for the first time found a fairground application. The new riding device was patented last year, this time by British inventors, and several examples are now in operation. In order to bring the survey up to date, the following description of this machine is offered. And as has so often happened in the past (commencing with the "Sea-on-Land" of 1880) the new device, known as "Jet Planes," has been invented jointly by a roundabout builder and an operator : in this case George Maxwell, of the Edinburgh roundabout building concern of that name, and John Hoadley, a well-known North Country showman.

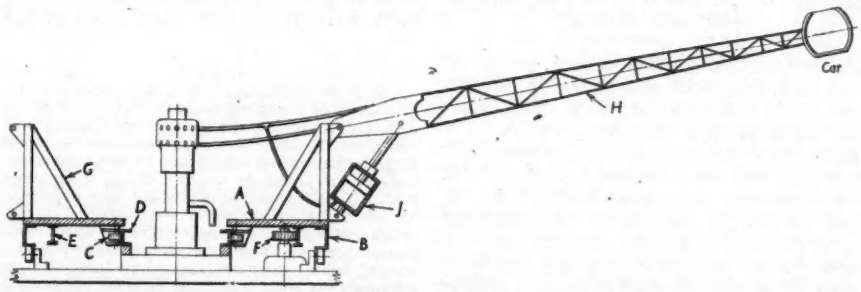


Fig. 1—The "Jet Planes." The car is raised and lowered at the will of the passenger through air pressure acting in cylinder J

Fig. 1 shows the jet plane machine in part cross-section. The revolving centre structure comprises an annular platform *A* attached to a channel ring *B* running on a series of plain rollers whose bearings are supported by the fixed base frame. A further series of rollers *C* are carried in bearings secured to the underside of *A*, and bear against a smaller channel ring *D* which is carried by the fixed base frame. The customary bar-tooth gear ring *E* is driven from an electric motor through reduction gearing and the pinion *F*. The platform *A* carries twelve heavy triangular frames *G*, bearings at whose upper ends carry the twelve arms *H*, at the outer ends of which are fitted the passenger cars. The closed ends of the ram cylinders *J* are pivoted to the bases of the frames *G*, and the rods attached to the pistons working in these cylinders are pivoted to the arms *H*. These arms therefore rise and fall as compressed air is admitted to or released from the ram cylinders, while moving over a circular course by electric power.

A central distributing valve is mounted on the base frame at the axis of revolution, flexible pipes being taken from the revolving head of this valve to the ram cylinders and to control valves fitted in the cars. This arrangement will be described with reference to Fig. 2.

The fixed base frame is extended to carry attachments for road wheel axles, so that it can form a towable road vehicle. The cars, arms, and ram cylinders are of course dismantled for transport. The extensions of the base frame are packed from the ground when the machine is in operation, providing adequate support longitudinally. Laterally, the base is made secure by hinged or removable outriggers, with jacks at their ends.

Fig. 2 shows in diagrammatic form the compressed air equipment. At the centre of rotation of the machine, a hollow pedestal *K* is fitted to the fixed base and supports by means of ball bearings a revolving valve casing *L*. The lower portion of *K* forms a cylinder in which a piston *M* operates. An upper piston *N*, of smaller diameter than *M*, is attached to the combined piston rod *P* by ball bearings. The main air supply is brought in at *Q*, and piston *M* can be by-passed by the operator's control valve *R*.

When the by-pass is closed, the underside of piston *M* is opened to atmosphere by means of this valve.

The valve casing *L* incorporates two sets of twelve ports, *S* and *T*. These sets of ports are covered and uncovered in turn as the pistons rise and fall, and the casing is surmounted by a spring loaded atmospheric valve *U*. The control valve assemblies in the twelve cars, only one of which is shown in Fig. 2, comprise two spring-loaded mushroom valves with passages arranged so that the opening of valve *V* connects together the pipes leading from ports *S* and *T* at the centre of the machine, and thence opens port *S* to the ram cylinder, the supply to which is "teed in" to the pipe from port *T*. Opening of the other mushroom valve, *W*, opens the ram cylinder to atmosphere. The passengers' control lever *X* can be used to open either valve at will, through the rocking arm *Y*, but not of course both simultaneously. When the lever is released, both valves close under the actions of their springs.

With the machine at rest, the underside of piston *M* open to atmosphere, and pistons *M* and *N* in their lower position, the cycle of operations is as follows :—

Having started the electric motor, the operator opens his by-pass valve *R*, equalising

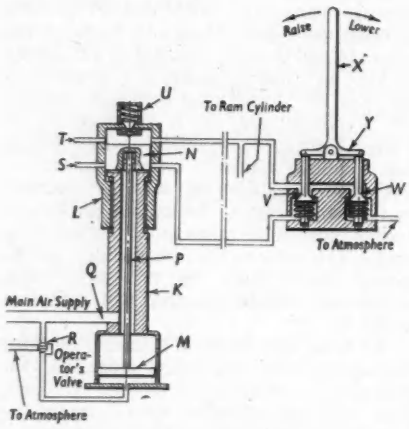


Fig. 2—Diagram of compressed air circuit. The passengers' control lever is on the right, the main control valve on the left

the pressure on the two faces of piston *M* and so causing both pistons to rise through pressure on the underside of *N*. This closes the set of ports *T* (air above the piston *N* being expelled through the atmospheric valve *U*), and opens the lower set of ports *S*. Any passenger can then cause his car to rise by opening his valve *V*, so admitting air to the appropriate ram cylinder. He can cause his car to descend by using the other valve *W* to open the ram cylinder to atmosphere, and so on throughout the ride. At the conclusion, the operator closes the by-pass valve *R* when he stops the electric motor. Since piston *M* is of greater area than *N*, the piston assembly will then descend, air below piston *M* being discharged to atmosphere. Descent of piston *N* cuts off the supply to the passengers' valves *V*, preventing further ascent ; and whether or not the passengers open their valves *W*, the cars will descend by their own weight, the contents of the ram cylinders being expelled through the ports *T* and the atmospheric valve *U*. The latter is set so as to give a safe rate of descent irrespective of the number of cars happening to be in a raised position, and allowing for possible use of valves *W* by riders.

All the air connections are made by means of flexible pipes clipped into position where

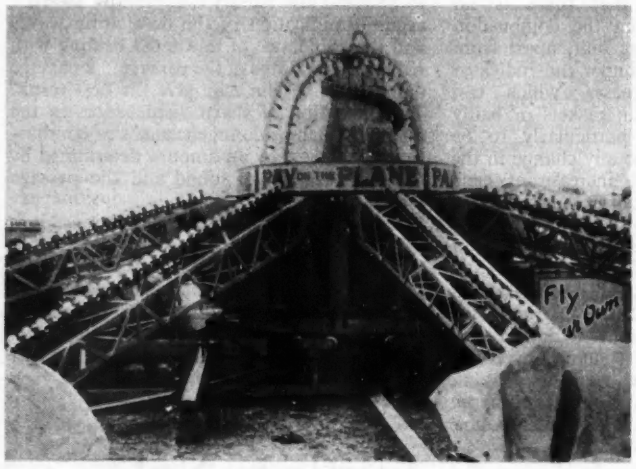


Fig. 3—"Jet Plane" fairground machine. The pneumatic ram cylinders for actuating the arms can be seen on the revolving centre structure

necessary. The starter for the motor, and the operators' valve *R*, are located in a paybox external to the circle of the machine. The air supply is obtained from a conventional portable diesel-driven compressor as used by public works contractors, with the addition of one or two supplementary reservoirs.

For transport, the arms, cars, paybox, surround fences, and supplementary reservoir can all be packed on one showman's truck of conventional size. The outriggers and other ancillaries pack on the centre truck ; these two vehicles and the compressor being well within the capacity of one diesel tractor.

An antecedent of this device, which was omitted from the previous series of articles, was the "Yo-Yo," introduced in the early 'thirties when the toy of that name became a national craze. Few were built, but one example travelled until about 1950. In this case, the centre turntable was larger, and driven through some of its supporting rollers. The arms were comparatively short, the possible vertical movement of the cars being small. The revolving centre structure was extended upwards, ties from its summit to the arms having strong tension springs incorporated in them. Passengers could set the cars into oscillation by pulling on ropes affixed to the top of the centre structure. The machine never achieved very much popularity, and, incidentally, its mechanical principle was quite dissimilar to that of the ingenious toy from which it took its name.

Deflections and Vibrations of Drilling Machines

INSTITUTION OF MECHANICAL ENGINEERS

At a meeting of the Institution of Mechanical engineers, held last Friday, December 9th, the following papers were presented and discussed :

SOME EXPERIMENTS ON THE DEFLECTIONS AND VIBRATIONS OF DRILLING MACHINES

By D. F. Galloway, B.Sc. (Eng.), Ph.D., Wh.Sc.*

Synopsis

The experiments described in this paper are part of a series of researches being carried out to obtain data for improving the design, construction and utilisation of production equipment, having regard to the increasing demand for such development which will be occasioned by the growth of automation. Research techniques and equipment were developed for examining the deflection and vibration characteristics of various drilling machines. Some comparisons were made between radial drilling machines, vertical drilling machines, and portal frame drilling machines, the latter type being included particularly because of the increased possibilities for its employment in unit construction automated lines. An account is given of the general experimental procedure and the special apparatus used. An analysis is made of the deflection characteristics of each type of machine, and examples are given of the magnitudes of the deflections. The principal natural frequencies of vibration of the machines were determined, and the vibration characteristics of the machines in drilling and facing operations were examined. Recommendations are made for the reduction of machine deflections and vibrations, and a basis for some machine design calculations is developed.

THE VIBRATIONS OF RADIAL DRILLING MACHINES UNDER TEST AND WORKING CONDITIONS

By S. A. Tobias, D.Sc., Ph.D.,† and Professor W. Fishwick, Ph.D.‡

Synopsis

Machine tool chatter is essentially a problem of dynamic instability. A drilling machine under working conditions can be regarded as a dynamic system which for certain values of its system parameters becomes unstable and bursts into oscillations. The system parameters are determined by the static and dynamic characteristics of the machine tool structure, the geometric shape of the drill, certain features of the workpiece material and the working conditions, and it is the interrelation of these which results in chatter or chatter-free machining. The paper commences with a discussion of the dynamic characteristics of radial drilling machines. This is followed by an experimental investigation of the behaviour of these machines under working conditions, and finally a theory of drilling chatter is developed. The results of this theory are presented in the form of a stability chart which shows those drill speeds at which, for given values of the system parameters, chatter-free drilling is ensured. Although the theory presented is based on an experimental investigation of radial drilling machines drilling into solid material, it is directly applicable to drilling operations carried out on any other type of machine and yields also results concerning chatter occurring at drill breakthrough and when drilling up predrilled holes.

Discussion

Mr. C. A. Sparkes : Scientific investigation into the behaviour of machine tools has been neglected for far too long. Some slight idea of the possible value of improving the performance of drilling machines can be judged from the fact that a machine tool maker with a total personnel of 450 drills about 180,000 holes a year. On that basis, the machine tool industry alone must be drilling about 18,000,000 holes a year. From these figures it is easy to see the benefit of even the slightest improvement in drilling machine efficiency.

Unfortunately, the present design of radial

* Director of Research, the Production Engineering Research Association of Great Britain.
† Assistant Director of Research, Department of Engineering, Cambridge University, formerly I.C.I. Research Fellow, University of Edinburgh.
‡ Professor of Electrical Engineering, University College, Swansea, formerly Lecturer, University of Edinburgh.

drilling machines, by reason of basic structure, is easily distorted under working conditions. The arm of a radial drilling machine is very much stronger than the pillar or the base, and that is probably one reason why the drilling machine people manage to incorporate such an enormous amount of electrical gear in the arm. One practical method of reducing deflections on this type of machine would be to use a tension bar between the drill head stop and the work piece or fixture.

In the interests of efficiency, I should like the authors to suggest an alternative way of dealing with vibrations other than supplying electrical energy to the driving motor only to have it dissipated in the heat of a dashpot. Greatly improved bore finish can be obtained by damping the bore bar through the medium of two supports. This provides considerable support in relation to metal removal and in relation to the question of vibration. The authors refer to the problem of vibration or chatter at the time of drill break through. This is well known in practice. Our operators usually disengage the power feed before chatter reaches serious dimensions, the completion of the drilling operation being performed by hand. A small indicator has recently been developed consisting of a cathode-ray tube excited through a vibration pick-up. By the use of this or a similar arrangement, it is possible to adjust the frequency response to that generated by the machine just prior to the break through. The information from the indicator could be used to control the power feed of the machine and thus eliminate hand operation.

Mr. P. Spear : I am extremely impressed by Dr. Galloway's use of a vibration suppressor. It seems to me that there are two main fields which should be studied, from the practical angle. There is first obviously the fundamental approach to the problem, but I should very much like to see hand in hand with that some idea of a device on the machine tool which can be adjusted to control or combat vibration from chatter. I also wonder whether Dr. Galloway, in his researches, has considered the possibility of applying this to press work from the medium and deep drawing angle. I was also impressed by the neatness of the technique used in the vibration recording instrumentation described in Dr. Galloway's paper. I wonder whether it is possible to obtain fuller details of it. The technique of splitting the circuitry so that one unit is essentially stationary and the other exploratory so that the two can be compared immediately is an extremely elegant method of research.

What has impressed me substantially throughout the papers is the really practical and fundamental application of force measurement. So often in metal cutting research one is asked to give advice to new laboratories which are being set up or to new people entering the field, and the first thing that people talk about seems to be force measurement, asking " What sort of dynamometer should we use ? " and so on, with little appreciation of the design and value of force measurement. This is one of the first papers in recent years whereby force measurement can be related in a really practical way to machine tool design.

Following through the emphasis in the papers on automation, it would appear to me that with the growing use of unit heads, and, what is more, the possibilities of standardisation of the elements of the unit heads, in the automatic or automation field, there should be some possibility of having some degree of standardisation in the chatter. The standardisation of unit heads is undoubtedly coming ; in many ways it is here. One of the largest companies in the country dealing with automation—as a user, not as a machine tool maker—has already had for some time standard designs for heads, fixtures and component parts. With the knowledge that the chatter is tied up with the moving parts and that that is the most important criterion and possibly the most difficult problem to solve, it seems that knowledge of the forces of the frequency characteristics will be extremely important in respect of the more static elements of the plant which are locating and holding the unit heads. I have in my mind the very great fear that many of the more static elements of the automatic plant may be designed by people with very little appreciation of the force system involved and very little appreciation of the importance of avoiding certain possibly critical frequencies.

Mr. D. D. Morgan : The complexities that surround machine tool vibrations and deflections may obscure the fact that both papers are in the long run directed towards two main ends : one, increasing drilling rates ; two, improving the quality of drilled holes. In other words, the authors have set out to help industry to drill better holes more quickly. It should be instructive to examine one or two aspects of the papers from that point of view.

In the diagram in his paper, Dr. Galloway has shown the variations in the slopes of holes drilled on radial arm and portal frame machines. Several very important facts emerge from an examination of this diagram. In the first place, the slopes are astonishingly large, even though the drilling operations were carried out under particularly good controlled conditions. Secondly, the portal frame machines are apparently no better, and even appear to be somewhat worse in this respect, than the radial drilling machines, despite the superior deflection characteristics of the portal frame machines. Thirdly, the variations in slope are obviously random in character. The deviations from correct alignment are much greater than can be explained either by changes in spindle slope due to machine deflections or by play in the spindle bearings. The explanation clearly lies elsewhere. It is probably related to the structural instability of the rotating drill, and to the way in which the chisel edge skids when it first makes contact with the workpiece. It can be shown that a drill point with an initial lateral displacement deviates from the true axis at an increasing rate as the drill penetrates the work. In some drilling tests in which pilot holes slightly larger in diameter than the width of the chisel edge were first drilled in steel, the slopes of the holes did not exceed twelve-thousandths of an inch per foot. This compares with slopes of up to about forty-five-thousandths of an inch per foot shown in the paper, and suggests that stability at the moment of entry of the drill into the work is distinctly improved if the cutting edges rather than the chisel edge first make contact with the work.

Dr. Tobias and Professor Fishwick have referred to another important aspect of the chisel edge. They suggest that the main cause of chatter at break through is the absence of the stabilising effect of the chisel edge. Somewhat surprisingly, they dismiss the sudden release of flexural energy as a secondary cause of chatter at break through. Dr. Galloway's paper shows that this energy may be considerable. It can be seen from this figure that over the comparatively short distance in which the drill breaks through an additional movement of about twenty-four-thousandths of an inch may be impressed on the drill feed. The system is dynamically unstable during the sudden release of this reservoir of strain energy, especially as it is released in a series of jerks as successive chips are broken off and shock waves which tend to initiate vibration may be set up.

Mr. A. I. Moore : The approximate calculations given in the first paper for the base of a machine show the relatively small contribution made by a concrete foundation of moderate depth to the static stiffness of the base. In this case the base of the machine was stiff enough in itself, but, of course, in other machines of different design the base may be considerably more flexible, in which case the concrete foundation becomes more important. The calculations confirm that in such cases a deep concrete foundation—possibly with reinforcement—must be used if large base deflections are to be avoided.

My second point refers to the errors in measurement of column deflections due to inaccurate settings of vee block and dial gauge as outlined in the first paper. When the vee block attachment is used in the measurement of column deflections, the percentage errors which may be encountered can be quite large. The diagram shows that inaccurate setting of the vee block is the main source of error, the error due to inaccurate setting of the dial gauge being small by comparison. As it is doubtful whether the vee block could be set visually to better than about ± 2 deg., it is evident that steps must be taken to ensure that the face of the vee block is perpendicular to the plane of measurement. By definition, the longitudinal and transverse planes of measurement are at 90 deg. to each other, so that if one vee block can be set parallel to the longitudinal plane a second one can be set parallel to the transverse plane with the aid of a square. The face of one vee block can be set parallel to the arm guides by utilising the movement of the drill head along the arm. By attaching a dial gauge to the head so that its stylus contacts the face of the vee block and traversing the head along the arm, any lack of parallelism will be shown by the dial gauge.

Dr. D. Williams (contribution read by the secretary) : In papers of this kind one is, I think, entitled to look for two things : first, a careful experimental exploration of the phenomena under investigation and, secondly, a set of recommendations on the best way to overcome existing faults and so ensure better designs in the future. The authors are to be congratulated on the way they have carried out the first of these two tasks, and any criticism must be confined to the second. The authors of both papers call attention to the desirability of greatly increasing the damping forces in drilling machines, particularly in the radial type, which appear to be the worst offenders in the matter of vibration. Dr. Galloway has tried using a tuned and damped vibration absorber and has obtained good results under certain conditions but, apart from this expedient, no concrete suggestion is made on how the necessary damping qualities are to be introduced. In the problem of aircraft wing vibration the same difficulty presents itself in an aggravated form, because any damping device has to be carried by the aircraft and must somehow be housed inside the wing structure. The natural tendency of an aeronautical engineer is, therefore, rightly or wrongly, to consider the problem of damping out vibrations in a machine tool as offering a great deal more scope for ingenuity. I cannot pretend to have made any study of the machine tool problem beyond glancing through the present papers, and I put forward one or two suggestions in a very tentative

way. In the first place, I see no future for the damped tuned vibration-absorber as commonly understood. This is satisfactory for overcoming a vibration of known mode and frequency, but is hardly feasible as a general palliative. In the conclusion to their paper, Dr. Tobias and Professor Fishwick say that the damping characteristics of a machine appear to be mainly determined by the damping properties of the foundation. They bring forward no evidence to prove this and, if it is true, their recommendation that a radial-drilling machine should be bolted to a stiff foundation does not make it easy to introduce any appreciable damping to the foundation. I would agree with their demand for stiffness in the foundation, and I would add massiveness as well. However, I would have thought that heavy damping of the structure of the machine itself would be a paying proposition. Since it is not feasible to subtract in any way from the existing structure, any method of introducing damping forces must entail adding something to it. What I have in mind is a vibration absorber that is rather different from the popular conception of this device, in that the auxiliary mass is of the same order as, or even heavier than, the equivalent main mass. This requires the natural frequency of the auxiliary system to be well below the fundamental natural frequency of the original or primary system. It will, of necessity, be lower than all the other natural frequencies of the primary system. This makes it effective whatever resonance mode is excited by the periodic forces induced by the drill.

It must be remembered, although the point is not specifically referred to in either paper, that the resonance amplitudes are very high indeed compared with the static amplitudes under the same force amplitude. Thus, from the data given, an oscillating force of 20 lb gives rise to amplitudes comparable with that caused by a static force of 1 ton. In other words, the vibration amplitude is about 100 times the static. This seems to offer a magnificent opportunity for solving the vibration problem by the judicious choice of a damped—but not critically tuned—vibration absorber.

I would locate the auxiliary damped sprung mass at the end of the radius arm, if that is at all practicable. This achieves two very desirable objectives ; it increases the ratio (effective mass)/(real mass), and it provides a valuable amount of inertia at the end of the arm, thus providing a kind of stabilising support for the arm where it is most needed. From the picture that Dr. Galloway shows of his vibration absorber, I would say that it is badly located for effective operation.

Mr. Ronald W. New : It may have been noticed that some differences of opinion relating to the interpretation of the vibrating shapes of a radial drilling machine occur in the two papers. In the second paper, the normal modes of vibration have been tentatively interpreted as the vertical rocking and tuning fork modes, and the horizontal rocking and torsional rocking modes, respectively. Tests on various machine tools have, however, shown that the vibrating shapes depicted in the first paper are really the first and second internal modes of vibration of the machine structure in the vertical direction. With the method of excitation shown in the first paper, the longitudinal rocking mode, with respect to the machine bed, does not usually show any sizeable response.

The question of the interpretation of the vibrating shapes is rather important. The chatter vibrations which can occur during normal machining operations are usually confined to the internal modes of vibration or to localised modes of individual machine tool elements. An exception to this statement could possibly occur in the case where a workpiece was positioned on the floor at the side of the machine base. With the radial arm swung over to align the spindle in the drilling position, both the longitudinal and transverse rocking modes of vibration would present further possible chatter vibration circuits. In a rocking mode, the machine could be described as vibrating in the manner of an inverted pendulous mass about the junction of the machine base with the supporting floor. It is a characteristic of these rocking modes that each part of the machine vibrates with the same angular displacement. Therefore, any differential vibration occurring between individual machine elements during rocking would be caused by inertia effects exciting on an internal mode of vibration of the machine structure. The extent to which the internal mode would be excited is governed by the closeness of the two natural frequencies respectively.

Referring specifically to the internal modes of vibration, their readiness to form the so-called chatter circuits is governed by the ease with which they respond to differential vibrations between the tool and the workpiece. The actual vibration characteristics in the internal modes are determined by the mass distribution, stiffness, and inherent damping of the elements which comprise the machine tool. Whilst response curves of machine tool structures often show several resonant frequencies, one of these may exhibit by far the greatest response to vibration. This is instanced by the first internal mode of vibration of the radial drilling machine. Although a similar large response exists in the horizontal direction to horizontal excitation, the thrust component during drilling is in the vertical direction. Therefore, it is reasonable to anticipate that the first internal mode of vibration in the vertical direction would form the chatter circuit. The lower response at the higher orders of internal modes of vibration is not really due to an increase in the effective dynamic stiffness when nodal points are introduced somewhere in the system. This increase in dynamic stiffness can be readily seen by recourse to the vibrating shapes of cantilevers at their higher modes.

Referring to the use of the vibrating shapes of machine tools, in addition to presenting a visual picture of the dynamic exertions of the structure from which weaknesses in it can be observed, they have a further purpose. Ultimately it is hoped that engineers will be able to calculate the principal natural frequencies and other vibration characteristics of apparently complicated machine tool structures by tabular systems similar to those used in other fields of engineering. Experimental data on vibrating shapes, &c., are being studied with this purpose in mind. However, sufficient data are not yet available for estimating the inherent damping in machine tool structures by calculation without recourse to vibration tests. Work is, however, under way both to study further applications of devices which will provide sufficient damping and to obtain a wide range of design parameters.

Mr. F. A. Lewis : Radial drilling machines are often built with the column and arm initially inclined towards the base, presumably to compensate for the deflections which occur under drilling loads. If terms are included for the weights of the head and arm, the deflection equations given in the paper readily permit the appropriateness of any initial misalignment of the machine to be examined over a range of thrust loads and over the range of positions of the drill head. There is a range of thrust loads where the variation in slope as the head and arm positions are varied is at a minimum. This is found to occur when the upward moment exerted by the drilling thrust is approximately equal to the downward moment due to the weights of the head and arm. It would appear, therefore, that a radial drilling machine is best adapted for use under conditions where the drilling thrust is in this region.

Mr. L. Bendelow presented a contribution by Mr. J. R. Ratcliff : In studying these interesting analytical papers, much as one appreciates the immense value of the work to machine tool designers, one cannot help regretting the superlative fits and fitting put into a machine to enable it to withstand forces which never ought to be imposed upon it. The radial drill is essentially a general-purpose machine ; yet very often it is used for batch production, in circumstances which allow us, if we choose, to relieve the arm of its cantilever bending, discount the fit of the arm collar, and practically eliminate bending moment from the column. I refer, of course, to the use of an outrigger tie or latch, so designed as to be quickly loosed from the work or the jig, and easily reclampable in a number of positions so as to retain the basic radial facility of the machine.

Mr. I. S. Morton, B.Sc. : Dr. Galloway refers to tests by the conventional alignment machine tool test charts. He also shows that radial drilling machines are invariably built with the column and arm inclined towards the base and generally the spindle inclined inwards by amounts up to 0·0012in per foot. These alignment charts were sponsored by this Institution in conjunction with the Institution of Production Engineers, so that not only are they therefore of interest to this Institution, but this Institution has a responsibility for them. In these charts it is assumed that the machine is built initially square ; that is, that the spindle is approximately perpendicular to the bed. I suggest, therefore, that some consideration should be given to revising these charts, which are still in constant use to take into account what is, in effect, the true state of affairs, particularly as these charts also have a deflection requirement which to me seems rather inadequately specified and could be improved.

Chatter is a very important and frequently encountered workshop problem. Yet I understand that Dr. Tobias and Professor Fishwick actually had difficulty in inducing chatter until they ran their machine without foundation. Can it be, therefore, that the solution to these practical problems is already closely at hand and that much of the trouble is simply due to bad workshop practice, as, for example, in incorrect clamping and support of the work, in which case, of course, the machine itself should not be blamed ?

Mr. E. G. Isherwood : Dr. Tobias and Professor Fishwick assume in their theoretical analysis that any increase in the thrust forces on the chisel edge is due solely to an increase in the penetration rate of the drill. The alternative assumption that part at least of the chisel edge thrust depends on the thickness of the chip removed by the chisel edge seems to be quite tenable having regard to the experimental data which the authors present. Admittedly, the chisel edge chip is small when compared with the chips removed by the cutting edges of the drill, but, bearing in mind the contrasting efficiencies of the two cutting actions, it is not unlikely that the thrust forces produced by equal increments in chip thickness are of

comparable magnitude for the two types of chip. In this connection reference may be made to a recent paper by Oxford,* in which the action of a drill chisel edge is compared with the cutting action of a tool having a very high negative rake angle of about—56 deg. If a chisel edge chip thickness effect of appreciable magnitude were to be found by future experimental work, the authors' theoretical analysis would have to undergo considerable revision. The authors' conclusions on drilling out predrilled holes are also affected, as are their conclusions on the desirable form of the curve of the drill thrust against feed.

Authors' Reply

Dr. D. F. Galloway (in reply) : One thing that stands out in my mind is the practical fact that I have experienced. I have seen many drilling operation difficulties in works, and have seen them overcome merely by putting the same drills and materials, with the same conditions of feed and speed, on to a portal frame machine. Therefore I feel that there is a great deal to be said, from the points of view of both the designer and the user, for trying to get conditions of design and utilisation approximating as closely as possible to those of the portal frame. The difficulty is that you cannot get in at the side. Industry should just examine how often it needs to use a radial machine. In many instances a line of radial machines is installed when many of the jobs to be done do not need the facility to go in from the side but could go between the beams. The part of the construction represented by the arms and beam is so cheap by comparison with the other types with solid or heavy type pillars that the money could quite easily be spent in doing what Mr. Spear has suggested, which is to have a table so that you can gauge movement one way with the table and movement the other way with the head.

Until people buy their own machines of that type or get the makers to build them, the problem is what to do with the bed. In the case of the radial drilling machine, first of all, would the user really take note of what the maker says ? The maker says " Put a block under it from 18in to 2ft thick." That is a fairly standard recommendation. Yet in not many factories do you see it done.

Several references have been made to the absorber put on the end of the radial arm. It was one that we developed. Someone asked whether absorbers work in practice. We have used absorbers on this type of machine and in other applications, and I can assure you that they work. They have limitations. One limitation was spotted by Dr. Williams, but his immediate solution, which is to have an absorber in which the mass is greater than the main mass, has obvious practical difficulties if you have to have a very large mass in the absorber. The important thing is not to regard the absorber as the panacea for all the ills in the machine. Let us have the absorber, if necessary, on top of good design and good utilisation.

Reference has been made to the alignment charts. I agree with what was said. I think they were probably out of date when they were printed. The sooner industry, because of its own desire, or the user, because of economic pressure, calls for a revision, the better. We now have a great deal more knowledge upon which to base a revision of the charts.

Dr. S. A. Tobias also made a short reply dealing with some of the points raised by speakers in the discussion.

* Oxford, C. J., *A.S.M.E. Transactions*, February, 1955. "On the Drilling of Metals : I.—Basic Mechanics of the Process."

Remote Indication of Alternator Field Current

IN modern power stations the central control room is usually some distance from the turbine room and difficulty may be experienced in providing the control room with remote indication of the alternator field current, which may be from 300 to 3000 amperes, d.c. Hitherto heavy-current shunts, directly connected into the alternator field circuit, have been used for measuring the current. For economic reasons, it is clearly necessary to restrict the heavy-current cabling between the exciter and generator to the shortest possible length. This means that the shunt must be located somewhere in the region of the generator or the exciter and that the light-gauge leads from the shunt to the indicating instrument in the control room will be of considerable length. It is evident that substantial errors may occur in the indication given by the instrument because of variations in the ambient temperature of the leads connecting the shunts to the indicating instruments. Furthermore, because of the necessarily low voltage-drop across the shunt the readings are particularly susceptible to variations resulting from defects in the instrument circuit.

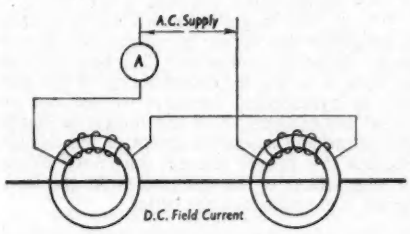


Fig. 1—Simplified diagram showing the use of transductors for remote indication of alternator field current

To avoid these difficulties the British Thomson-Houston Company, Ltd., Rugby, has developed a method of using transductors for the metering of field currents.* When used for d.c. metering the transductor can be described as a "d.c. current transformer."

A d.c. current transformer consists essentially of a magnetic circuit embraced by two separate windings. One winding is in series with the circuit carrying the direct current which is to be measured. The other winding is connected across any convenient low voltage a.c. supply, e.g. 110V or 240V. It is in this a.c. circuit that the meter is connected, and the current in it is always proportional to the current flowing in the other winding for the following reasons.

The d.c. winding is connected in series with a highly inductive circuit, i.e. the generator rotor, which effectively prevents any rapid change of direct current, and this latter can, therefore, be regarded as constant when considering the principles of operation of the d.c. current transformer.

The effect produced by any current in the secondary a.c. winding is alternately to buck and boost the magnetomotive force produced by the steady direct current. As the magnetic core of the transductor is highly saturated by the passage of the direct current alone, any additional magnetomotive force due to any instantaneous flow of current in the a.c. winding in the same sense will produce negligible additional flux and, therefore, no back electromotive force. If, therefore, additional steps were not taken as described below there would be no limit to the value of current flowing in the a.c. winding in the alternate half-cycles concerned.

During the intervening half-cycles, however, the current in the a.c. winding produces a magnetomotive force in the opposite sense to that produced by the d.c. winding. As the magnetic circuit is initially saturated by the direct current, the initial impedance offered to the alternating current is very low, and the value rises very steeply until the magnetomotive force is equal and opposite to that produced by the d.c. winding. At this point the core becomes demagnetised, a rapid flux change occurs, and a high back electromotive force is induced, thus limiting any further increase of current in the a.c. winding. The effect is, therefore, to produce in effect a square wave of alternating current whose value is limited to that laid down by the value of direct current flowing in the primary winding at the time.

It remains, therefore, to cut out the alternate half-cycles when the a.c. is not metered by the d.c. The usual solution is to connect two single-phase units in series opposition (as shown in the accompanying diagram) so that the a.c. current flow is restricted to the correct value in every half-cycle by one or other of the two units, while the other unit is idling. By this means an alternating current of substantially rectangular wave form, having a peak value proportional to the direct current flowing in the primary winding, is produced and this can be measured either on an alternating current instrument, or, if preferred, a rectifier instrument may be used.

The two transductor units can be of any shape, i.e. wound on ring cores or rectangular cores, and they can be two separate physical units or combined by using a three-leg core, the principle in every case remaining unchanged. Usually the d.c. winding is a single turn, i.e. it becomes a bar-primary.

The accuracy obtained depends largely on the magnetic characteristic of the core material ; high accuracy—as in the case of a.c. current transformers—necessitates high permeability special alloys. Ratio error in the case of field current measurement is usually specified as not to exceed 1 per cent, but better accuracy can be obtained if necessary. The error within wide limits is independent of load, as the impedance offered by the a.c. winding swamps any other impedance in the circuit, and accuracy is maintained for a wide metering range, e.g. 25 to 125 per cent of rated current.

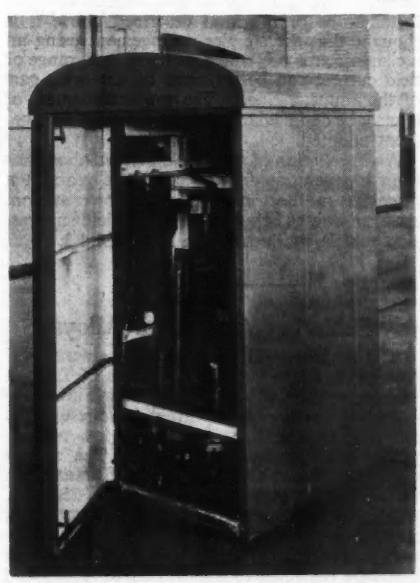


Fig. 2—Transductor for measuring excitation fitted in field suppression cubicle in a C.E.A. power station

Another advantage of this arrangement is that it is not affected either by variation in

* British Patent No. 691382.

impressed voltage and/or frequency. A consistent reading is, therefore, obtained which is not liable to drift due to temperature variations or any of the other troubles which are known to affect the conventional shunt and millivoltmeter arrangement for the measurement of direct current. The normal precautions applicable to conventional current transformers, such as centring of bar-primaries, proximity of return conductors, should, of course, be observed.

A further advantage of the arrangement described is that the exciter circuit, which is a high-power circuit, subject occasionally to high transient voltages, is left completely insulated from the instrument circuits, which are inherently vulnerable to faults of this kind. The danger of

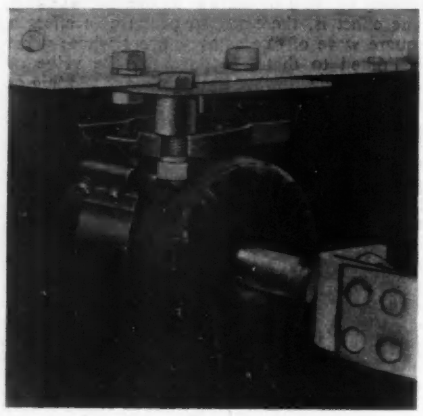


Fig. 3—Detail of fitting of transductor in field suppression cubicle

heavy short circuits in the control room is therefore avoided and risk to personnel reduced.

The secondary current can either be measured directly by an a.c. ammeter, or a rectifier can be included to permit the use of a d.c. moving coil instrument. With either arrangement additional instruments can be incorporated readily without affecting the accuracy of the indication. For installations of the kind described above it is thought that the simpler arrangement using an a.c. ammeter is preferable, as the normal range of field current can be arranged on the open part of the ammeter scale. The equipment must, of course, be designed to suit the particular arrangement adopted.

An installation of the kind described above has been in operation for the last three years at a large Central Electricity Authority power station, the transductor being fitted in the field suppression cubicle, as illustrated in Figs. 2 and 3.

Soldering Aluminium Alloys

RECENT investigations into the soldering of aluminium alloys at the laboratories of Tiltman Langley, Ltd., Redhill, Surrey, under a Ministry of Supply development contract, have resulted in a simple tinning technique and a low melting point, corrosion resisting solder. The special solder contains a high proportion of tin and can be worked at temperatures of about 250 deg. Cent., so that high-strength aluminium alloys can be joined without their mechanical properties suffering. The solder has also shown a very high resistance to corrosion in salt spray and humidity tests, one solder composition being suitable for a wide range of light alloys. The shear strength of the soldered joint is 2½ tons per square inch, and this is expected to allow narrower lap joints than riveting or resin bonding.

The tinning technique is to heat the metal on an electric hot plate and melt the solder on it. The solder is then spread with a shrouded brush of glass fibres ; the fibres remove the oxide film from the surface and the liquid solder prevents it reforming. No flux is used ; any slag floating on the tinning is removed with the brush. The same tool is used to remove excess solder and leave a neat fillet when two parts have been joined.

Britain's Energy Prospects*

By Dr. G. H. DANIEL, D.Phil.†

THE British economy has been bounding ahead in recent years at a rate perhaps faster than in any other period for which we have reliable information, and it is natural that the prudent mind should ask whether the large increases in energy supplies that are a precondition of such expansion will continue to be forthcoming. At the Margate Conference this summer, when the great field of industrial advance opened up by the automatic factory was discussed, the President of the Institution of Production Engineers made it clear that automation would only be successfully implemented if certain requirements were met, among them sufficient power supplies to support higher productive effort. The difficulties encountered in meeting the demand for energy in recent years are well known and give emphasis to the question whether shortage of energy supplies is going to be the pit into which we shall fall in our fast pursuit of ever bigger output and standards of living.

Whether this danger will or will not be avoided is something that cannot be prophesied and this paper makes no predictions. The best that can be done is to try, by consideration of the past and by hypothetical estimates worked out on stated assumptions about the future, to clarify the nature and assess the extent of the danger. Because this danger requires the united efforts of large sectors of the nation to avoid, the more widely it is understood the better.

PRESENT CONSUMPTION OF ENERGY

In the modern world energy is, in the words of Clerk Maxwell, " the go of things " and the intensity of its use is a rough measure of the degree of industrialisation. The primary fuel now used inside this country is equivalent to some 250 million tons of coal a year ; the equivalent of a further nine million tons is used to bunker foreign-going vessels and that of 23 million tons is exported[1]. Total inland consumption in Britain ranks third after that of the United States and the Soviet Union. Our consumption per head is about five tons a year or about two-thirds that of the United States, intermediate between that of Canada and Sweden and nearly five times the world average. Over a quarter of our fuel is used in residential premises and the annual consumption of the remainder (nearly seven tons per person employed) tends to be concentrated in certain industries. In light manufacturing, agriculture and office work, it is less than three tons of coal equivalent per employee. In transport and mines and quarries, it is about 17 tons. In bricks, cement, chemicals and non-ferrous metals it is over 20 tons, and in iron- and steel-making about 60 tons.

TOTAL DEMAND FOR ENERGY IN THE FUTURE

Looking at it in terms of the total consumption of primary fuel expressed in millions of tons of coal equivalent, how is the total demand for energy likely to grow ? Obviously much depends on the speed with which the economic system as a whole is going to expand and, because our purpose must be to obtain a measure of the maximum burden that may fall on fuel supplies, as buoyant a view as can reasonably be justified must be taken about the possible rate of expansion.

An ambitious target for the expansion of economic activity is that suggested by the Chancellor—doubling the standard of living in 25 years. Because of the increase in population, this implies a growth rate of 3 per cent a year compound in the national income or enough to multiply it by about 2·1. If, as the Report of the Committee on the Economic and the Financial Problems of the Provision for Old Age[2] suggests, the working population increases by about 4·6 per cent, the required increase in productivity (as measured by national output per head of working population) is 2·8 per cent a year compound. This is almost the rate of increase achieved between 1948 and 1954, excluding the recession year of 1952. It is much higher than the average increase recorded over the periods 1870–1913 or 1920–1938. It will only be possible if the rate of investment in productive industry and the basic services can be greatly speeded up—perhaps doubled—and if exports of goods and services do rather better than keep pace with the big expansion in imports that will follow from the growth in the material requirements of industry and the expansion of consumer demands. It is a modest rate in relation to the growth rates achieved in some foreign countries, particularly those with a large reservoir of rural population from which industry can draw. And it does not seem impracticable when viewed from the standpoint of the opportunities and stimuli that new technical and scientific developments provide. But it would represent a great success if achieved in Britain and it can, therefore, be taken as the basis for a maximum estimate of fuel demand. A low estimate representing very indifferent success in the economic field would be an increase of 3 per cent a year in only, say, four years out of seven, the other three years recording no net increase because of recession ; this implies an average growth rate of 1·6 per cent a year in productivity or approximately the average increase over the inter-war period.

What relationship will exist between expanding activity and fuel consumption ? Between 1948 and 1954 fuel consumption rose about 15 per cent, while real income rose by 20 per cent. But in this period consumption was stimulated by armaments, the removal of restrictions on street and shop lighting and petrol, fast growth of aircraft fuel consumption, the setting up of oil refineries to replace imports of refined petroleum products and the development of the atomic energy establishments. Some of these factors will either not be repeated at all in future or will not have as big an effect on fuel requirements as in the last six years and for this reason we might expect fuel consumption to increase at a slower rate than 0·75 of the rate of increase in national income, perhaps at something nearer the 0·65 to which the ratio has fallen in the last two years.

The total amount of human energy employed in the modern economy is less than about 1 per cent of the total energy consumption and is not all employed for control purposes. The overwhelming contribution is from coal and oil and the increase needed in their consumption to enable electrical power to replace as much of the human control element as can be envisaged is not very significant. Finally, by reducing machine idling time, the space heating, lighting and other overheads and the proportion of spoilt work, the application of automatic control systems can be confidently expected to lower the fuel consumption per unit of output.[3] My general conclusion is, therefore, that automation will speed up the increase in industrial production and reduce the fuel consumption per unit of output. The increase in industrial production already postulated for doubling the standard of living is a very rapid one, which will probably require the full help of automation to realise. The role of automation will be to make the achievement of this production target easier and slightly less expensive in terms of fuel than the 0·75 relationship for the last six years would suggest. The saving cannot be large because it can arise only from an increase in an already fast rate of progress and because progress will necessarily be limited to a fairly small sector of the total field of consumption.

The prospect of getting a still lower ratio between the increase in fuel consumption and that in national output through speeding up the rate of improvement in the efficiency of fuel-using appliances is less encouraging. There are some promising large fields for saving—for instance, by further electrification of the collieries and the railways and the greater use of diesel engines. But the emphasis on ever-increasing

* Abstract. ' Viscount Nuffield paper, Institution of Production Engineers, London, December 15, 1955.

† Ministry of Fuel and Power.

‡ It is assumed that 1 ton of oil is equivalent to 1·7 tons of coal, and that (based on the yield in thermal power stations) 1700 units of hydro-electricity are equivalent to a ton of coal. The consumption figures are estimates for 1955.

[1] Cmd. 9333 of December, 1954.

[3] The results obtained with one of the transfer machines installed by Austins at their Longbridge works are interesting. This machine is reported to produce more than the thirteen separate machines it replaced, with big savings in labour, floor space and materials, and a 50 per cent reduction in power consumption per unit of output, even before making allowance for savings in lighting and space heating. (See F. Griffiths, " Why Austin Developed Unit Construction Transfer Machines," *The Machinist*, January 21, 1955.)

speeds in transport is an offsetting factor and the use of black oils for burning is extending to applications where the economies to be made by substituting it for coal are less than in earlier years. Radical inventions for economic large-scale production of electricity from fuel cells would, of course, alter the long-term prospect considerably, but we must wait until they are made before counting on them ; in any case they could hardly affect the prospect for the two or three decades immediately ahead.

How all these factors will balance out no one can predict, but if we take the alternatives of fuel consumption increasing by 0·6 and 0·7 per cent for every 1 per cent increase in national income, then with national income doubling in twenty-five years fuel consumption might grow as follows :—

TABLE I—*Total Inland Fuel Consumption—High Estimate*

	Assuming that for every 1 per cent increase in national output there is an increase in fuel consumption of :	
	0·7 per cent	0·6 per cent
	(Million tons of coal equivalent a year)	
1954	245	245
1960	278	273
1965	309	299
1970	342	326
1975	377	354
1980	415	385
1985	458	418

NOTE.—The coal equivalent of coke exports and non-fuel petroleum products is excluded.

If the development in national income was at the lower inter-war period rate referred to earlier, and if fuel consumption increased 0·6 times as fast, growth would be at the substantially lower rate shown by the following figures :—

TABLE II—*Total Inland Fuel Consumption—Low Estimate*

	(Million tons of coal equivalent)
1954	245
1960	261
1965	277
1970	291
1975	305
1980	320
1985	332

The difference between these various estimates is over 100 million tons by 1985 and is sufficient warning of the dangers of long-term forecasting.

THE DEMAND FOR THE MAIN FUELS

Industry.—Among the many contributors to the national output, the pacemaker is manufacturing industry. Between 1948 and 1954 the total contribution of the others (including transport, building, fuel industries, distribution services, defence, &c.) grew at 2 per cent a year. Assuming that it continues to grow at this rate, the output of the manufacturing trades will need to be multiplied about two and a half times if the assumed total growth in the national income during the next thirty years is to be achieved. A close relationship has existed since the end of the war between fuel consumption and the output of manufacturing industry (excluding iron and steel). The index of consumption has been proportional to the 0·65th power of the index of production and, if this continues to hold, industrial fuel consumption (excluding iron and steel) might grow from 67,500,000 tons of coal equivalent in 1954 to 95,000,000 tons in 1965, 122 million tons in 1975 and 152 million tons in 1985. Within this total the part played by electricity and oil should grow appreciably.

The steel industry will have a big part to play in an industrial expansion of the kind we are considering and, during the next few decades, its growth is unlikely to be seriously slowed down by the light metals. A doubling of steel output by 1980 does not seem unlikely. The prospect of coke being replaced for blast furnace use is still a distant one for this country, though as the result of continuing improvements in efficiency the use of coke should not increase as fast as the output of iron. The steel plants' use of electricity is certain to grow rapidly, and further expansion can be expected in their use of oil.

Agriculture is a promising market for fuel and power. The heated greenhouse is a profitable way of growing food, and soil warming and sterilisation are increasing. It may take nearly a ton of coke to produce a ton of dried grass, and grain and grass driers are finding increasing favour. It is also found advantageous to keep livestock—particularly poultry and pigs—warm. The use of electricity on farms has been growing at an average rate of 20 per cent per annum in the last six years and, even after the last scattered farm has been joined up to the public supply, the scope for wider use of electricity for lighting and heating farm buildings and providing power for machinery and appliances will result in continued growth. The use of diesel oil in tractors, which has more than doubled in the last six years, can also be expected to continue although this is at the moment being more than offset by the decline in use of the less efficient vaporising oil.

Residential Premises.—A broad generalisation which might be applied with reserve to the future is that total residential fuel consumption increases at nearly half the speed of the national product. Within this, the expansion of electricity can be expected to be very fast, because of its falling price relative to other fuels and most other items of personal expenditure, and because its convenience and its close association with many of the gadgets and amenities of modern living make its increased use one of the main consequences of higher incomes.[4] Further expansion in the domestic demand for oil is also likely while the use of raw coal and of gas may decline.

Railways.—The advantages of electric and diesel locomotives have now been admitted by the staunchest supporters of the steam engine and the railways' new plan[5] is based on a shift to these forms of traction. By 1970 the railways' consumption of coal may be reduced to about 5,000,000 tons a year, while that of electricity may have doubled and that of oil have reached 1,000,000 tons. By 1985 the use of electricity may have doubled again and the use of coal reduced to not much more than about 1,000,000 tons a year.

[The author also considered road and air transport, bunkering and fuel exports.]

Summary.—The estimates for each sector of inland consumption and for bunkers suggested by the above considerations may be summarised as follows :

The total inland consumption suggested by the sector estimates lies between the two estimates given in Table I and corresponds to an increase in fuel consumption at about 0·63 times the rate of increase in the national income. Although interesting, this result does not, of course prove that the future relationship will be less than the 0·7 used for the higher estimate in Table I. The sector estimates suggest that growth will be mainly in industry—particularly the manufacturing trades—domestic premises and miscellaneous users (commercial premises, public buildings, &c.). There should be a substantial fall in railway and colliery consumption. The increase in road transport is slower than might otherwise be expected because of replacement of motor spirit by derv fuel.

Demand for electricity will grow fast, perhaps as in Table IV.

These estimates are slightly higher than those given in last February's White Paper presenting *A Programme for Nuclear Power*,[6] the difference partly reflecting the improved long-term prospect opened up by nuclear power itself. It is true, of course, that electricity cannot continue indefinitely (or, indeed, for many years) to grow at a fast rate. There are limits to the proportion of total investment that can be devoted to power stations and electricity consuming appliances. But the present estimates, which allow for a slowing down in the rate of growth and for a smaller ratio of increase in electricity supply to increase in national output than obtained in 1954, still leave the level of consumption in 1985 below the likely saturation level.

The increase for the carbonisation industries, though significant, is less substantial and arises mainly from the need for metallurgical coke. Extension of the iron and steel industry's coke requirement is assumed to be from 17½ to 31 million tons between 1954 and 1985 and the demand for gas may grow from 3 milliard therms to 4½ milliard therms. The total fuel requirements of the carbonisation industry would then develop from 53,000,000 tons of coal equivalent in 1954 to 76,000,000 tons in 1985, a part of this being met by oil.

If (and the qualification is important) present relationships in coal and oil prices continue and there are no difficulties about the supply of the principal products required, the demand for oil can be expected to swell enormously. Since the end of the war, the average rate of growth of petroleum fuels (including bunkers and refineries) has been about 8 per cent a year and the 1955 usage is about 25,000,000 tons of oil. Growth in recent years has been fast for transport uses and faster still for the black oils burned in boilers and furnaces. Inland consumption of black oils

TABLE III—*Estimate of Demand for Primary Fuel in the Principal Consuming Sectors*

	1954	1960	1965	1970	1975	1980	1985
	(Million tons of coal equivalent)						
Agriculture	2·8	3	4	5	6	6	7
Iron and steel	32·5	39	44	49	54	59	64
Manufacturing	67·6	82	95	108	122	136	152
Collieries	11·4	10	8	8	7	7	7
Refineries	3·3	4	5	6	7	7	7
Total, industry	117·6	138	156	176	196	215	237
Railways	15·0	13½	11½	9	8	7½	7
Other transport	17·3	21	23½	26	28	29½	31
Domestic	65·3	69	73	78	83	88	94
Miscellaneous	29·4	34	38	43	48	54	60
Total, inland	244·6	275½	302	332	363	394	429
Foreign bunkers	9·0	9	9½	9½	10	10	10½
Total	253·6	283½	311	341½	373	404	439½

NOTES :
(1) The consuming sectors are the sectors of final consumption. the electricity, coke and gas used in these sectors being expressed in terms of the primary fuel needed to produce them.
(2) 1 ton of oil products is assumed to be equal to 1·7 tons of coal. 1 ton of gas coke=1 ton of coal and 1 ton of metallurgical coke=1·3 tons of coal. Electricity is expressed in tons of coal on the basis that a ton of coal yielded 1650 units in 1954 and that the yield will increase to 2300 units in thirty years' time.

TABLE IV—*Electricity*

	Domestic	Industrial, including agriculture	Other	Total	Electricity required to be sent out	Fuel required by power stations (million tons of coal equivalent)	Required capacity of power stations (million kWI at mid-year)
1954	18	32	13	63	70	42	20½
1960	26	49	19	94	105	56	29
1965	33	68	27	128	142	71	38
1970	40	90	34	164	181	86	47
1975	50	114	45	209	231	104	58
1980	62	139	57	258	284	123	70
1985	74	165	69	308	339	145	82

[4] The following figures from Wilkins, L. T., "Domestic Utilisation of Heating Appliances and Expenditure on Fuels in 1948–49," *The Social Survey*, 1951, illustrate this :

	Estimated expenditure in 1948–49 on : Electricity	All other fuel
	£ s.	£ s.
Householders with a weekly income of under £3	2 2	12 10
£3 15s.	3 11	14 3
£5 10s.	6 2	16 8
£10 10s.	8 6	19 2
£20 and over	16 5	19 3

[5] British Transport Commission : *Modernisation and Re-equipment of British Railways*, London, 1955.

[6] Cmd. 9389

(excluding derv and refinery fuels) so far this year has been 19 per cent more than in the same period of last year. This rise in consumption—mainly in manufacturing industries—is due to be supplemented by the big increases in the use of oil at power stations which are to be made in pursuance of the Government's policy that more oil should be used in order to fill the gap in coal supplies.[7] The gas industry is planning to extend oil gasification and the use of refinery tail gases and surplus products. If these plans are realised, the inland consumption of oil in 1965 can be expected to be about 45,000,000 tons a year, of which about 6,000,000 tons will be used in power stations. Its technical advantages and the favourable movement of its price relative to that of coal in recent decades already makes oil an attractive replacement for coal in important parts of the coal market. If there are no difficulties in supplying the products demanded (particularly the black oils) the demand for oil will certainly not ebb after 1965, but can be expected to flow still further into the energy market. On these assumptions, demand might well continue to rise as shown in Table V.

TABLE V—*Oil*

Possible demand for oil for inland consumption and bunkers if economic activity grows fast, present price relationships continue and there are no difficulties of oil supply.

	1954	1960	1965	1970	1975	1980	1985
	(Million tons of oil)						
Light oils	8·7	10½	11½	12	12	12½	12½
Black oils :							
Road and rail	1·4	2½	3	4½	5	6	7
Industry (including agriculture)	4·2	10½	16	29	37	44	50½
Power stations	0·2	5	6				
Domestic, gasworks and other	2·0	4½	6	7	8½	10	11
Total, black oils	7·8	22½	31	40½	50½	60	68½
Refinery fuel	1·9	2½	3	3½	4	4	4
Total inland oil	18·4	35½	45½	56	66½	76½	85
Bunkers	3·8	4½	4½	5	5½	5½	6
Total inland and bunkers	22·2	40	50	61	72	82	91

NOTE.—The light oils cover aviation fuels, motor spirit, kerosene and light products for gas making. The black oils cover gas, diesel and fuel oil. Petroleum products not used as fuels are excluded.

SUPPLIES OF PRIMARY FUEL

Coal.—Considering all coal in seams 14in or more thick and up to 4000ft deep, the total reserve is estimated to be of the order of 170 milliard tons or over 700 times the present annual rate of extraction.[8] But it is not the coal in the ground that matters so much as the difficulties and cost of extracting it, and the shortages of particular types of coal (for instance, of coking and gas coals).

The estimated reserve of coal in the ground gives an exaggerated impression of the amount of coal available for use. A substantial part will have to be left in the ground because extraction cannot be complete. The amount of recoverable coal has not been closely assessed in Britain,[9] but the American experience is illuminating. The United States' reserves were originally estimated by Campbell as 3100 milliard tons. More careful work showed that much of the coal inferred to exist in continuous seams was absent, and the present estimate of the U.S. Geological Survey of the amount in the ground is 1900 milliard tons.[10] About 40 per cent of this is thought to be in beds so thin or deep as to involve a doubling of present mining costs. If coal with an ash or sulphur content that is not commercially acceptable is excluded, and if it is further assumed that the present percentage of recovery in United States mines (only 50 per cent) continues, the estimated recoverable coal is only about 600 milliard tons or a fifth of the original figure. This estimate errs on the side of excessive caution ; Europe is already working less attractive coals than assumed in the calculation, and its recovery percentage is about 75. But the general warning that the American experience gives about the over-optimism of estimates of coal in the ground remains good.

Another point to be made about coal production is that it is one of the most labour intensive of all major industries, and this has grave consequences for the price of coal. Although a great deal of mechanical and electrical energy is employed in the mines—so much so that, in terms of its horsepower equivalent, human labour does not account for more than about 1 per cent of the total energy used—the tasks of pumping and ventilating the mine and moving coal and rock require a large use of energy, and hard human labour in dark and dangerous conditions remains the key feature of the industry. The proportion of the total cost of production accounted for by wages has always been high and, there having been comparatively little increase in labour productivity, it has declined little over the last hundred years and is much higher than in manufacturing. Whereas in the factory trades the total wage bill is only two-fifths of the total net value of the work done, in coal mining it is nearly four-fifths. Now two of the characteristics of the long-term development of the country are the rise in wage rates and prices, the former rising faster than the latter as real earnings increase and hours of work fall. Under these conditions an industry with a relatively high proportion of wage costs and whose labour productivity is, for the reasons indicated earlier, increasing more slowly than in other industries, will inevitably suffer a bigger increase in total costs than other industries.

For similar reasons the improvement in national standards of living that takes the form of better working conditions, shorter hours, longer holidays and improved sickness and accident benefits are of special significance to the mining industry. The pressure for these improvements naturally tends to be high because of the arduous and dangerous nature of the work. As other industries, which find it easier to do so, improve working conditions, the mining industry must follow suit in order to maintain its labour force. The effect on its production costs is particularly serious.

These deep-seated difficulties have been aggravated by the unfortunate developments of the period 1913–1945. The collapse of the export and bunker trade and the stagnation of the inland market led to a fall in total demand for coal from 287 million tons to 188 million tons a year—a fall of more than a third. In the financial state the industry was in, investment was inevitably very low and took more the form of new machinery giving quick returns, than of new pits ; only a fifth of the industry's output at nationalisation came from mines that had been sunk during the preceding thirty years. Two world wars intensified the shrinkage of productive capacity and the weakening of the administrative and professional cadre. The failure to sink new pits or carry out major reconstructions was lamentable because a pit cannot be sunk faster than the limited amount of human and mechanical energy that can be concentrated at its bottom makes possible ; ten years may be needed in practice before it is brought into production. The small number of first-rate mining engineers with experience of carrying through large schemes, who were left in the industry at the end of the war was no less serious.

What are the prospects for increased coal output ? I am not going to try to give a figure, but will only emphasise two points. The first is that no quick increase can be expected. It was only in 1952 that investment in the industry was substantially increased and no returns from the current high level of capital expenditure can be expected for some years. The second is that there is no prospect of cheap coal. The easily-mined coal in this country has long been dug up and consumed. The high proportion of wage costs in the industry means that as general standards of living rise, the impact of higher wages and reduced hours of work is much greater on it than on other industries. There will be no easy gains in labour productivity to offset this factor. The best hope lies in large-scale introduction of machine mining, but this and the new pits will be expensive and will involve a corresponding increase in capital charges per ton of coal mined. It would be most unsafe to assume that the long-term trend of increase in the real price of coal will not continue. These may be disappointing statements. The deep coal mines offer no easy rewards. A facile estimate of their future output could do much more harm than good. It is more important to have an understanding of the difficulties that have to be overcome.

Oil.—Although oil consumption is now growing so fast that it is carrying the greater part of the total increase in energy consumption, and although the industry should be able to sustain this fast increase for many years, the long-term prospects for sufficient supplies being available are doubtful. So far, as the result of great expenditures and the most advanced methods of discovery, the industry has been strikingly successful in maintaining, and indeed increasing, the ratio of proved reserves to annual production. Proved reserves are now over 21 milliard tons or about thirty times the annual rate of world production, new discoveries are continually being made, vast areas still remain unexplored, and no doubt many large new fields remain to be discovered. Growing emphasis on reservoir engineering, both in primary and secondary recovery, ensures that an increasing proportion of "oil in place" is recovered. On the other hand, the demand for liquid fuels is going up rapidly in all countries. It is hard to see fields as prolific as those of Texas, Venezuela, Iran and Kuwait continuing to be discovered as rapidly as in the past, and some of the big existing fields have passed their peak yields. Already there are signs that the fall in the real price of oil that has taken place in the last fifty years will not be continued.[11] Development of oil reserves at great depths and on the Continental shelves will naturally be expensive and so will extraction of the remnants of oil from the old fields. Oil from shale and tar sands will not be cheap. Although their precise extent is a matter for speculation, the remaining reserves of oil are certainly much less than those of coal. It would seem wise to anticipate that before the end of the century the oil companies of the Western World will be encountering difficulties in maintaining the expansion of supplies. For the period that we are considering, however, there is a reasonable expectation that the necessary supplies will be forthcoming although they may well be at a higher real price at the end of the period than at the beginning.

A further problem is presented by the bad balance of the likely growth in demand as between the main products. The oil industry has developed mainly as a producer of the more refined products—fuel oil being mainly a by-product of this development and its landed value in this country being normally below that of crude oil. But the growth of demand is likely to be much faster for the heavy than the light end of the refinery range. Table V suggests that by 1975 the demand for aviation fuel, motor spirit and kerosene will be only a sixth of the total demand for petroleum fuel and that by 1985 it will only be a seventh. Present refinery out-turn is about three-tenths in the form of the more expensive light oils. The companies may

[7] Hansard, July 20, 1955, Col. 388.

[8] World Power Conference, *Statistical Yearbook No.* 7, 1954.

[9] A good recent account of British coal reserves, though not quantitative in character, is Mr. E. H. Browne's "The Coalfields of Great Britain and their Future Development," *Trans. Institution of Mining Engineers*, 1954–5, Vol. 114, Part 8.

[10] Averitt, Berryhill and Taylor, "Coal Resources of the United States," U.S. Geological Survey, Washington, D.C., 1953.

[11] Mr. F. C. Waddams, in his recent (October 4, 1955) address to the Institute of Petroleum on "Investment in the Oil Industry," draws attention to the tendency for the return on capital employed in the industry to fall because of rising costs.

be able to do something towards offsetting this trend in demand away from the light products by balancing the trade in countries like the United States, where the demand is greater for the light end of the range. The use of crude oils containing a high proportion of fuel oil will help and so will the addition to diesel and fuel oils of certain light fractions not now in them. But the trend in other countries is also in favour of faster growth of black oils, and in due course diminution in the availability of natural gas may push the United States in the same direction. It is hard, therefore, to envisage the pattern of growth set out in Table V developing without an eventual increase in the price of the black oils relative to the light and without the price of fuel oil creeping closer to, or perhaps even exceeding, that of crude oil.

Water Power.—The resources of water power in Britain are limited, the bulk of them (sufficient to save about 5,000,000 tons of coal a year at thermal power stations) being in the Scottish Highlands and the total for the whole country being no more than would save 7,000,000 tons of coal a year.[12] The amount already developed is only sufficient to save about 1,000,000 tons of coal a year and most of the remaining potential is relatively costly to develop and more suitable for peak, than base, load operation. Development is, however, going ahead in the North of Scotland and it is possible that water power will be saving 2,000,000 tons of coal a year by 1970 and 3,000,000 tons a year by 1985.

Nuclear Power.—The prospect for continued growth and prosperity of the population of this and other countries would be brutally short but for the promise of nuclear energy. Last August's International Conference at Geneva showed that the United States, the Soviet Union, Canada and Britain are far advanced in the development of commercial power stations using nuclear energy. The papers submitted were remarkably unanimous on the economics of these stations. The capital costs of the early types already in course of construction will be about twice those of conventional power stations and the percentage "burn up" of atomic fuel will be low. Even so (provided the stations are operated at a high load factor, and reasonable offset is made for the plutonium produced) the final cost of electricity is expected to be less than 0·6d. per unit and so fully competitive with conventional stations in Britain, though not generally speaking in the United States, where the conventional fuels are cheaper. The scientists are confident that these early types will bear little more relation to later developments than did the early cars or aeroplanes. Capital costs are predicted to fall to the level of the conventional power station and the "burn up" of fuel should increase until something like a third of the total energy in the nuclear fuel is utilised. From the present stage when a ton of uranium can be made to do the work of about 10,000 tons of coal, the point should be reached where it will replace 1,000,000 tons of coal. The cost of electricity may drop to about 0·3d. per unit generated. This is in pleasing contrast to the prospects of the stations burning conventional fuels which cannot now look forward to being able to generate for much less than 0·7d. per unit.

Until recently no serious search had been made for uranium, but the rate of mineral discovery has probably never been as fast as it has been for uranium in the last two decades. Major commercial discoveries have been made in widely scattered localities from the refuse heaps of the South African gold mines to Rum Jungle in Australia, and from Beaverlodge and Blind River in Canada to Laguna and Poison Canyon in New Mexico. There are important deposits in the Congo, Central Europe, Utah, and many other places. Although exploration is still in its early stages, the known reserves of the producing nations of the West alone include over 1,000,000 tons of uranium that can be produced at a cost of less than £4 per pound for U_3O_8 in high-grade concentrate. Several million tons more can be produced at up to £10 per pound and there are very much larger quantities (including, for instance, the enormous phosphate and shale deposits of Mexico, the United States and the Baltic countries) which have lower concentrations of uranium, but which may still be commercially worth working, particularly if associated minerals —for instance, shale oil—are exploited at the same time. The known reserves have, in fact, a heat content several times greater than the world's total reserves of the conventional fuels and the uranium production already developed suffices for a world-wide programme of nuclear power development.[13] In addition, there are in India, Ceylon, Brazil, the United States and elsewhere important reserves of thorium, which has good prospects of use in advanced types of reactors. Moreover, there is a chance of securing the controlled release of energy from nuclear fusion, so enabling light elements like deuterium and lithium to be added to the list of fuels.

The information released during the last few months already makes the estimates of the future of atomic energy given in February's White Paper on *A Programme of Nuclear Power* appear conservative. But the programme envisaged in the White Paper is extremely ambitious. We have not yet a nuclear power station in production and until some of the existing projects have been successfully hatched it would seem unwise to count on beating this programme. We may hope, therefore, that nuclear energy will be replacing 6,000,000 tons of coal by 1965 and perhaps 40,000,000 tons of coal by 1975. Thereafter it seems possible that all new generating capacity will be of this kind, there being no problem of restricting nuclear stations to base load operation because by then their capital cost will have fallen close to that of conventional stations, and stations will have been developed of a type sufficiently flexible for medium load operation. On this basis nuclear energy would be doing the work of 94,000,000 tons of coal a year by 1985, and would then constitute nearly two-thirds of the fuel consumed at power stations. In addition, nuclear energy is likely to be developed for other purposes—in particular for ship propulsion and as a source of heat for industrial plants with a large process and space heating requirement.

Other Sources of Energy.—There are a number of other sources of energy that are being investigated at present or are being developed on a pilot plant scale. Some of these, for instance, those aiming at direct use of solar energy and the fuel cells which aim at direct production of electrical energy and the freeing of power production from the limitations of the Carnot cycle, would, if successful, have a significance comparable with the development of nuclear energy. The discovery of large quantities of natural gas would revolutionise the prospects of the gas industry. But these possibilities are still remote. Others—for instance, underground gasification, peat utilisation, methane drainage and wind power—offer more definite prospects of a small, but still useful, contribution to energy supplies during the next two or three decades.

Conclusions

Having surveyed the problem from both sides, what can now be said about the possibilities of supplying enough primary fuel to meet the growth in demand for energy during the next thirty years ? If economic expansion is no faster than in the inter-war period, there should be no shortage of fuel, though there will be various problems of adjustment as the newer sources are developed ; a moderate increase in oil during the next decade and, thereafter, a modest nuclear power programme, should suffice to make up for any deficiencies in coal supplies. But can supplies be made available to sustain an expansion fast enough to enable the standard of living to be doubled in a generation ? The estimates made in this paper suggest that the maximum increase in inland fuel requirements that might be expected under these circumstances is that shown in Table I—from 245 million tons of coal equivalent in 1954 to 458 million tons in 1985. Detailed consideration of the factors determining consumption and of the prospects in individual sectors suggests that this increase is too big, but it may be adopted in order to be on the safe side. Adding bunkers and an arbitrary figure of 10,000,000 tons for coal exports, the highest estimate of the total demand it seems reasonable to consider is one rising from 269 million tons of coal equivalent in 1954 to 329 million tons in 1955, 397 million tons in 1975, and 479 million tons in 1985. The nuclear power programme now in hand is hoped to contribute the equivalent of 40,000,000 tons of coal a year by 1975 and a further extension to 94,000,000 tons a year by 1985 would seem possible. Satisfaction of the growth in oil demand sketched out in Table V would increase energy supplies from the equivalent of 38,000,000 tons of coal in 1954 to 1.5 million tons in 1985. Finally, the expansion of hydro-electric capacity, use of nuclear power for ship propulsion and process heating and development of new techniques like underground gasification might contribute at least 5,000,000 tons of coal equivalent a year by the end of the period. The part of demand remaining for coal would then rise from 230 million tons in 1954[14] to a peak of about 240 million tons in 1970. Only in the following years would the pressure on coal be eased by the massive injection of nuclear power and fifteen years later in 1985 the demand for coal would still be about 225 million tons.

Marshalling of supplies in this way would satisfy the biggest demand that need be envisaged, and at first sight the figures seem very reassuring, since they indicate a task for the coal industry that is below the target of 240 million to 250 million tons that the National Coal Board has set itself.[15] But this gives no grounds for satisfaction. The experience of the last four years has given a good hint of the difficulties of expanding coal output. Output in 1955 is likely to fall slightly short of that of 1951. With other industries, whose competitive position is stronger, striving to grasp more labour, mining manpower may go on declining, and great efforts will be needed to offset this and the natural loss of mining capacity. As standards of living improve the miner will want to reduce his hours of work and increase his holidays. Moreover, this year's likely total output of about 222 million tons of coal includes a substantial marginal tonnage that cannot be maintained indefinitely ; besides the output from high-cost mines, it includes over 11,000,000 tons of coal got on Saturdays and over 11,000,000 tons of coal got from opencast workings. Large investments will be needed for many years if we are to produce 225 million to 240 million tons a year of reasonably priced coal over the next thirty years.

Contemplation of the contribution that we have assumed from oil and nuclear power destroys any lingering sense of complacency. The Atomic Energy Authority and the oil companies between them are being counted on to carry out the stupendous task of providing in the space of thirty years new sources of energy equivalent to over 210 million tons of coal a year. The coal industry in its heydays took about twice as long to expand output by this amount. Obviously, much hangs on the success of Calder Hall and its successors. Even the amazing capacities of the oil companies will be taxed to execute the plans that have been made for the expansion of oil supplies during the next decade and to provide for further growth thereafter. The companies will have to overcome great difficulties in discovering sufficient new supplies of inexpensive crude oil and in coping with the likely shift in the balance of demand for the main products. The import bill for oil will rise to impressive levels. Inability of the companies to meet the whole of the demand for oil or of the nation to earn enough from its export trade to pay the bill would shift more responsibility on to coal. The latter would have to take the place of fuel oil and possibly, by means of oil-from-coal plants, supplement the supply of light oils and middle distillates. Whether all these great tasks will be achieved no one can predict. The best we can do is to try to assess their possible magnitude and bend our efforts to their accomplishment.

[12] See Williamson, James : "Water Power Development in Great Britain," *Engineering*, Vol. 168, No. 4372, 1949, and Peattie, J. D., and Fulton, A. A., "Integration of Hydro and Thermal Generation in Great Britain." World Power Conference, Rio de Janeiro, 1954.

[13] See Johnson, Jessie, "Nuclear Fuel for the World Power Programme." International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1955—Paper 470.

[14] In 1954 requirements exceeded home production by about 6,000,000 tons, of which roughly half was met by imports and half by reduction of stocks.

[15] In *Plan for Coal*, London, 1950, the National Coal Board set a target of 240 million tons a year by 1961–65. This figure was subsequently increased to 250 million tons.

LETTERS AND LITERATURE

Letter to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

RESILIENCE OF A GYMNASIUM FLOOR

SIR,—If the correspondence on the subject of sprung floors were governed by some sort of referee, in the same way as the effusions of committee members are kept in check by the chairman, I might have been spared the task of pointing out the irrelevance of Mr. R. W. Muncey's letter (THE ENGINEER, November 11th) on that subject.

Mr. Muncey has two main points to make in his letter. They are :

(i) That experiments have shown that, under walking conditions, the pressure on the foot, particularly the heel, and the time-variation of that pressure, do not differ significantly whether the floor is concrete, joist-supported boards, or ¼in cork tiles laid on concrete ; on lawn the pressures are comparable, but the shape of the first part of the pressure-time curve is different.

(ii) That blindfolded persons walking on concrete and on joist-supported boards—both linoleum covered—were unable to distinguish the one from the other.

Without, for the moment, discussing the merits of these statements, I must point out to Mr. Muncey that neither statement is relevant to the question at issue, interesting as no doubt each is in itself. What I may refer to as the main irrelevance lies in the fact that his data do not apply to a sprung floor, but only to different types of solid floors, and to solid floors covered by different materials, such as cork and linoleum. He does not seem to have seen my last letter (THE ENGINEER, October 14th), or he would have noted that I took pains to distinguish clearly between sprung floors and solid floors covered by some resilient material. In the first paragraph of that letter I said :

" The pleasant feeling that a resilient floor gives under impact is thus due, not so much to the ' give ' of the floor as to the fact that it cannot deflect without causing a transfer of momentum from the descending body to the generalised masses that are associated with the ' normal modes ' of vibration of the floor. This explains why a thick rubber sheet spread over a rigid floor is in no way a substitute for a sprung floor, and also why the wearing of rubber-soled shoes is equally ineffective—in neither case is there a transfer of momentum."

This quotation, in conjunction with what I have said above sufficiently bears out my charge of irrelevance.

As a further indication of the muddled thinking with which I must charge Mr. Muncey, I will quote the following statement of his :—" These results " (i.e. heel pressure measurements on concrete, cork and lawn) " conflicted with our preconceived ideas, which were based on lines of thought similar to those of Dr. Williams." I do not know what preconceived ideas Mr. Muncey had on these relative pressures ; all I know—and I challenge him to contradict me—is that I expressed none in the two letters that have, so far, appeared under my name.

Having now, as I hope, made it clear that the data Mr. Muncey has brought forward in no way confute, or even bear upon, my original argument, I feel that it would be a kindness to Mr. Muncey, and a matter of interest to your readers, to explain what his data really signify. Taken at their face value these data look a little odd, and it is easy for a person without " engineering insight " to misinterpret them. Referring again to Mr. Muncey's data as given at (i) and (ii) above, one finds that he comes to the surprising conclusion that the reason for the similarity of pressures in (i) is that the foot comfort provided by the pad of flesh under the heel masks the effect of the differences in floor hardness. This leads him to the equally surprising implication that, judging by the pressure records, there is nothing to choose, in this matter of comfort, between walking on a grass lawn and walking on concrete—no wonder such an interpretation conflicted with his preconceived ideas !

What, then, is the real explanation of the similarity in overall foot pressure when walking on these very different surfaces ? The answer, in my view, is bound up with the word walking. The exercise of walking differs fundamentally from running or jumping in that :

(*a*) impact forces are of a different order of magnitude.

(*b*) The maximum foot reaction in walking is a static force differing little from the weight of the walker.

With regard to item (*a*) it is clear that, in walking, the c.g. rise and fall is very small indeed, since one foot is always in contact with the ground. The leg flexes just enough to allow the foot to clear the ground, and anyone can check for himself that, just before dropping to the ground at the end of its forward travel, the heel is no more than an inch or two above the floor surface. Any impact involved is therefore due to that short drop of the heel to the ground. The reaction due to this is small compared with the full weight of the body which quickly follows. As the weight of the body is the same, whether the foot momentarily supporting it rests on concrete, lawn, or deep sand, the small impact of the heel affects the shape of only the initial part of the pressure-time curve, leaving the maximum pressure, the time to maximum, and the time back again to zero pressure, much the same for all three floor types. Thus it is the smallness of the initial impact, combined with the general similarity in the rise and fall of the main pressure (equal to the weight of the body in each case), that gives the same overall appearance to the pressure-time curve that Mr. Muncey has noted. It is now commonly accepted that discomfort is to be measured by rate of change of acceleration (and therefore of force) rather than by acceleration itself, and it is the initial accelerations following the first heel-ground contact that determine foot comfort. Mr. Muncey has noted the dissimilarities in this respect, but has apparently missed their significance.

With regard to item (ii) above, it is not surprising that blindfolded persons were unable to distinguish the difference between two solid floors when both were covered by linoleum. The small initial heel impact cannot be much different for the two solid surfaces, and any chance of distinguishing between a concrete and a joist-supported board floor must disappear when each is covered by a material that is softer than either. If the comparison had been made between uncovered concrete and cork-tiled concrete the result of the test would, I think, have been very different.

I would emphasise again that the above remarks apply only to the exercise of walking. In running and jumping, the foot-impact shocks are far greater and the maximum pressure may be many times the weight of the body. The result is that a soft covering, that would make a wonderful improvement to a concrete floor for walking, would be of little account as a protection from shock in a 4ft high jump on to the same floor. It is then that the sprung floor comes into its own. Perhaps, Sir, in conclusion, you will allow me to express a little surprise that this correspondence has not so far evoked any response from designers of sprung floors. Is one to understand by this, I wonder, that building sprung floors is regarded as an art rather than a science ? If it is so regarded, then the sooner a little science enters into the design of such floors the better. For, although traditional methods based on long experience of trial and error very often attain a surprising degree of effectiveness, no radical advance in design can be expected without departing from such methods.

D. WILLIAMS

Farnborough,
Hants,
December 7th.

Literature

An Introduction to Fluvial Hydraulics. By SERGE LELIAVSKY. London : Constable and Co., Ltd., 10 and 12, Orange Street, W.C.2. Price 30s.

ENGINEERS have much cause for gratitude to Dr. Leliavsky. As readers of this journal in particular will recall, he has for many years been a lucid contributor to the literature on such subjects as open-channel flow, hydraulic and soil-mechanics problems arising in connection with river control and irrigation works and, indeed, the hydraulic problems of structural design. In the early part of this year we were greatly impressed* by his first volume on " Irrigation and Hydraulic Design," and we much appreciate the present, smaller, work on the flow in rivers and canals in erodible channels. The author's qualifications for covering a comparatively wide range of subjects are based on the distinguished positions, quoted on the book's title page, which he has occupied, during his long and very active career both as a practical engineer and as a professor, in the hydro-electric and irrigation fields in Russia and in Egypt. All his publications testify to an originality and liveliness of mind, a width of interest and a range of study and comprehension of original papers in many languages, which are indeed rare.

The aim of Dr. Leliavsky's latest book

* See the review in THE ENGINEER, May 27, 1955, page 743.

is to bring together material on the various theories, methods of observation and analysis, and some data, concerning the effect of the flow of water on an erodible bed and the converse effect of the shape of the eroded channel on the flow pattern. He starts with a philosophical note on the "two alternative approaches to the sediment transportation problem." The dilemma in which the research engineer may find himself when searching for general laws and formulæ —in other subjects as well as in that of river hydraulics—is well brought out here: either he can aim at finding the forces and other mechanical factors which cause a submerged solid particle to be lifted from the bed of a channel and to remain in suspension; or he can attempt to derive, from measurement of the characteristic dimensions of channels and of their bed material, formulæ which, because they fit the data resulting from past measurement, may be expected equally to describe other existing rivers or canals yet to be constructed. Whilst the first school elucidates the physics of the problem and aims at understanding each step in the process, the second is satisfied with a description of the final result. The author, very fairly, gives equal attention to the study of the developments and the conclusions arrived at by both schools, for he recognises that for ultimate success in a full understanding of any problems the methods of the first school must be followed, whereas—so far—practical design criteria have largely been the result of the work of the second, empirical, school. He recognises equally, however, that members of both schools have attempted to bridge the gap separating them, the scientists by using the data and formulæ of the empiricists on which to test their physically and dimensionally rigorously derived formulæ, and the engineers by casting their empirical "laws" in forms which, according to the principles of mechanics, would be expected to give a general picture of the process and might indeed be capable of extrapolation beyond the range of the basic observations.

After defining the difference between traction of "bed load" and suspension of "suspended sediment," the author deals with the correlation between the surface slope (i.e. the energy gradient) of the river and the particle size of the bed material; with dunes and ripples; with basic scour criteria: "pick-up" velocity, drag and lift; with bed-load discharge according to the drag theory and other methods; and with the stability of side slopes. The chapter on three-dimensional characteristics of the water flow in rivers and the "non-parallelism principle" which refers to the secondary motions observed both in natural and artificial channels is of particular interest when related to current research, both in the laboratory and in the field, which —whilst no less laborious than the other researches into various aspects of river hydraulics—is hoped to result, in the near future, in an appreciable advance in our understanding of these phenomena. The author then proceeds to discuss in further detail the mechanical explanations of sediment suspension, and concludes with a major chapter on the empirical approach to the sediment transportation problem and on empirically derived formulæ.

It may be expected that Dr. Leliavsky, like other authors of books on subjects which are still in the course of intensive study and development, will be criticised for not including the latest researches—such as those by Brig. R. A. Bagnold†—in his treatment, or for including material which is as yet incomplete or inconclusive. Another criticism which may be expected will be directed at the irritating misprints and mis-spellings of names of some well-known authors. Such criticisms, however, are trivial when the general merits of Dr. Leliavsky's book are considered: it will doubtless be of great interest to the specialist in any one of the fields of river hydraulics, and of great assistance to the numerous engineers who, at one time or another, are concerned with the design of rivers, canals, or works in or adjacent to such channels.

† See, for example, *Proc. I.C.E.*, Part III, Vol. 4, No. 1, April, 1955.

Analysis of Feedback Control Systems. By ROBERT A. BRUNS and ROBERT M. SAUNDERS. London: McGraw-Hill Publishing Co., Ltd., 95, Farringdon Street, E.C.4. Price 53s. 6d.

THE last five or six years have seen the publication of a number of books presenting a unified theory covering all forms of feedback control systems. On the practical side, such systems embrace the fields of mechanical, electrical and process engineering, and the control engineer must necessarily be versatile in training and outlook. On the other hand, much of the basic theory has a certain affinity with alternating current circuit theory, and for this reason may be more easily assimilated by the electrical engineer than by others. The book under review is intended to provide an introduction to the subject "consistent with the technological background of the average person new to the field." The authors assume that the student is familiar with the fundamental laws of dynamics, steady-state a.c. circuit theory, the solution of elementary differential equations, and the elementary properties of complex numbers. The methods of analysis used in the book are based almost entirely on the harmonic response function, and the classical methods of solution (via the differential equation) are only discussed where necessary to provide a basis for the harmonic response method. In general the book avoids the more advanced mathematical methods, and whilst this results in the exclusion of some powerful techniques, such as the Laplace Transform, the approach adopted will undoubtedly appeal to the student of average mathematical knowledge, and should also be of interest to the practising engineer, who in many cases may be concerned with semi-empirical solutions.

In the introductory chapter the authors define the feedback control system, and with the aid of a few simple examples describe the various kinds of system and their properties. A brief résumé is also given of the method of treatment to be followed throughout the book. The remainder of the book is divided into two parts. Part I deals with the properties of control system components, with, of course, special reference to their harmonic response. There is a chapter on the dynamics of mechanical systems, followed by chapters on electric servomotors, hydraulic, pneumatic, and electric circuits, electronic, magnetic and rotary amplifiers, reference standards, and error detectors. It is clearly impossible in a book of this size to cover such a variety of subjects in any great detail, and for the sake of conciseness a good deal of underlying theory is also taken for granted. Nevertheless, this portion of the book provides a useful and fairly comprehensive survey.

Part II of the book deals with feedback system theory, starting with a discussion of performance specifications, the graphical presentation of harmonic response data, both as gain and phase characteristics and in polar diagram form, and the Nyquist stability criterion. Succeeding chapters deal with the reduction of actual systems to block diagram form, the use of forward and feedback correction to improve performance, and the determination of the transient response from harmonic response data (including the root-locus method). There are chapters on non-linear and discontinuous systems, in which a brief description is given of the phase-plane and other available methods of analysis. There is also an interesting chapter on the experimental determination of transfer functions. Electric analogues are often used throughout the book, and their practical application in analogue computers (servo-simulators) is briefly mentioned.

From the teaching aspect a valuable feature of the book is the large number of worked examples, many of which are drawn from a wide range of practical applications. Also included are a large number of similar problems to be worked out by the reader. A separate bibliography is not given, but footnotes are extensively used to enable the reader to refer to more specialised literature. The book is well written and should form a useful addition to the literature on this subject.

Hydraulic and Pneumatic Operation of Machines. By H. C. TOWN, M.I.Mech.E., M.I.Prod.E. London: Odhams Press, Ltd., 96, Long Acre, W.C.2. Price 21s.

OVER the past twenty years or so the use of hydraulic and compressed air power for the operation and control of machines, machine tools and industrial plant has steadily increased, and new applications to take advantage of fluids and air under pressure are still being introduced. Hydraulic and pneumatic mechanisms have been responsible for considerable savings in manpower and the speeding of operations in all branches of industry, and their extensive use makes it essential for engineers and students to have a good general knowledge of the principles of their design and construction. It is the object of this book to provide such knowledge, based upon the latest practice, in a concise form.

In the book the author deals in a clear, practical way with the principal aspects of the design of equipment and its application. The first part dealing with hydraulic operation covers fluid power and pump units, valve gear, circuits, rotary drive, machine tool operation, hydraulic presses, accumulator systems and hydrokinetic transmission and automotive controls. The second part on pneumatic operation describes air compressors, pneumatic tools, circuits, air-operated jigs and fixtures, industrial applications of pneumatic power, and hydro-pneumatic operation. Each subject is dealt with concisely with the help of explanatory diagrams and drawings. Students will find this a useful text book on hydraulic and pneumatic operation of machines, whilst designers and engineers will find it a handy source of reference for information previously obtainable only from a number of sources.

Books Received

Practical Construction of Warships. Second edition. By R. N. Newton. London: Longmans, Green and Co., Ltd., 6 and 7, Clifford Street, W.1. Price 50s.

Fire Protection Year Book, 1956. Sixteenth edition. Compiled by F. D. Pratt. London: Benn Brothers, Ltd., Bouverie House, Fleet Street, E.C.4. Price 12s. 6d.

Electrical Engineers' Reference Book. Eighth edition. Edited by E. Molloy. London: George Newnes, Ltd., Tower House, Southampton Street, Strand, W.C.2. Price 70s.

Negligence and the Designer

By A. H. BOULTON, LL.B., F.C.I.S.

TOWARDS the end of November, 1951, the motor vessel "Waziristan," manœuvring in the lock at Avonmouth docks, came into collision with the tug "Sea Queen," and in so doing caused damage not only to the "Sea Queen" but also to the lock gates and to herself. More than three years later, on February 18, 1955, the circumstances of this mishap were reviewed in a judgment recorded by Mr. Justice Willmer in the case Hindustan Steam Shipping Company Ltd. *v.* Siemens Bros. and Co., Ltd., and as a result the law of negligence has been carried a step forward in a direction liable to affect every engineer concerned with problems of design.

The collision had occurred because the "Waziristan" had moved forward under the influence of engines set at "full ahead," when the officer on the bridge had not intended to give any such order to the engine room. The owners of the vessel, plaintiffs in the case, alleged that this was due to a fault of design in the engine room telegraph, and that the manufacturers of the telegraph ought to be made responsible for the damage which resulted from this fault. The learned judge found on the evidence that the telegraph was not faulty in design, and for this reason, amongst others, the case went against the plaintiffs. The interest of the case, however, consists in the consideration by the court of the question whether, in law, the manufacturers would have been liable if the design had been faulty in a manner constituting negligence on their part. This question had not been considered in any of the previous cases based on allegations of negligence on the part of the manufacturers of goods.

It is frequently commented that negligence constitutes a branch of law which is always in a state of change. There are some branches of the law where this is not so, but in which the doctrines established in the past call for modification only rarely. Negligence, however, is a breach of the duty to take care, and because continuing technical progress and the increasing complexity of the social pattern have the result that one person's care or carelessness affect more and more people, the categories of negligence are continuously tending to extend. In order to understand the significance of the judgment in the "Waziristan" case it will be well to review the history of the law regarding the liability of manufacturers to users of their products.

Traditionally, the purchasers of goods have been subject to the maxim *caveat emptor*, "let the buyer beware." The Sale of Goods Act of 1893, codifying a number of principles which had been developed and expounded in the courts in the course of centuries, provided that certain warranties and conditions should attach to the contract of sale, having the effect that the buyer was not left to depend exclusively upon his own astuteness in avoiding the consequences of buying defective goods. Until recently, however, the matter remained one affecting the relationship of the immediate buyer and seller, and the manufacturer, as such, was not held to have any clearly defined obligations apart from those contained in any guarantees he might voluntarily give. This position, however, was profoundly modified by the famous case of Donoghue *v.* Stevenson, which for twenty-three years has stood as the ruling case in the matter of the responsibility of the manufacturer to the users of his product.

This was a Scottish case, which, like the "Waziristan" case, went against the plaintiff on the facts, but in which the Scottish court stated a case to the House of Lords for a definition of the law on the basis of the facts as alleged by the plaintiff. The allegation was that a bottle of ginger beer—not, it is important to note, a glass bottle, but an opaque bottle—had contained the remains of a decomposed snail. The consumption, or perhaps the sight, of this, had, it was alleged, made the lady ill who had drunk the ginger beer. The court subsequently found that the facts did not support the allegation, that there never was a snail in the bottle, but in the meantime the House of Lords had given their judgment, which was that where the manufacturer of goods prepares them in such a way that they reach the ultimate consumer without intermediate examination being possible, then, if as a result of the negligence of the manufacturers in the manufacture or the making up of the goods the consumer suffers damage, the manufacturer is liable.

In a number of cases since Donoghue *v.* Stevenson the principle has been explored. On the basis of the original case it could be applied authoritatively only to articles of food and medicine, but this has been widened. An attempt was made in one case to fasten liability on auditors for the consequences of a mistake in a balance sheet, which has this only in common with a snail in ginger beer, that it ought not be there. This, however, was going a little too far for the Appeal Court, and the argument did not succeed. In the cases which had come before the courts prior to the "Waziristan" case, however, the basis of the claim was always some intrinsic fault in the article, so that it could be said that it was not in fact what it purported to be.

In the "Waziristan" case, however, the plaintiffs did not and could not allege that they did not get the thing they bargained for, namely, a Siemens engine-room telegraph. There was no secret about the method of its working. They admitted having specified it when the ship was built because of its excellent repute and they did not claim that it differed in any way from other telegraphs of the same manufacture, nor from what they had been led to expect. What they did allege was that when the instrument had been switched off the pointer remained on the dial in a position which could mislead, that this was a fault of design which constituted a trap, and that the manufacturer should be held liable for the damage which resulted.

After due consideration of the fact that his decision involved an extension of the principle as previously recognised, Mr. Justice Willmer decided that the principle of the manufacturer's liability for defective goods could be applied where the fault alleged was one of design only. The basic principle had been expressed in the judgment in Donoghue *v.* Stevenson in the words: "You must take reasonable care to avoid acts or omissions which you can reasonably foresee would be likely to injure your neighbour."

The decision was that the argument applied. The argument did not succeed, for three reasons. First, the facts did not, in the opinion of the court, support the plaintiffs' case. Secondly, the mishap came as the culmination of a chapter of accidents which the defendant manufacturers could not reasonably have been expected to foresee. Thirdly, there was abundant opportunity for the plaintiffs' engineers to have examined every detail of the telegraph's working between its installation and the accident. But the argument applied, and unless and until this decision is overruled by a superior court it must be accepted as the law that where, through a defect of design attributable to negligence on the part of the manufacturer, the use of a product suffers damage, having used that product in circumstances in which he has had no reasonable opportunity of intermediate examination, the manufacturer will be liable.

This is a far-reaching development of the law, and it remains to be seen what limits will be set to its extension. The practical question which will arise will be "how grievous must a fault of design be to constitute negligence?" This will turn upon the degree of foresight the designer is expected to possess in visualising possible failures and their consequences. It is a principle of the law that damages include all the consequences which could be reasonably foreseen, and it is manifest that the consequences of faults of design in some products, for example, signalling systems or braking devices, could be very serious indeed. Thus, although in the "Waziristan" case the defendants succeeded, the case has brought to light a liability of which engineers in general and designers in particular should be made aware.

The English judiciary has long enjoyed a reputation for reasonableness, and for wisdom in its guidance of the growth of the law through the cases. In the "Waziristan" case some words of Mr. Justice Willmer are particularly worthy of record, although they were spoken, as the lawyers say, *obiter*—that is, by the way and not as constituting part of the reason for the decision in the particular case. "I wish to make it clear that just because on this occasion I acquit them of the charge of negligence brought against them, it does not by any means follow that the same result would obtain in any proceedings brought in the future. As is well known, there is nothing static in relation to the question as to what amounts to 'reasonable care.' With the advancement of scientific knowledge and the acquisition of experience, that which is excusable to-day may well be blameworthy tomorrow."

This statement, although in itself having no authority, is bound to be persuasive in any future case turning on the principle of liability for negligence in design, and if it is upheld it will mean that when any mishap draws attention to a fault in design, the remedying of that fault, which the reputable manufacturer already accepts as a moral duty, will become a legal obligation, since the failure to remedy it will constitute a failure to take that degree of care which the law demands under sanction of the infliction of damages.

SOCIETY OF CHEMICAL INDUSTRY.—The Society of Chemical Industry has stated that its seventy-fifth annual meeting will be held in London next year, the general theme of the proceedings being "Achievements of Industrial Chemistry." The lectures to be delivered will be such as to enable speakers to review the major advances brought about by the work of industrial chemists in the last twenty-five years, and to look forward over the next twenty-five years to the centenary of the Society. It is intended that there shall be two parallel series of lectures, each of four. One series will deal with the products of industrial chemistry, the new processes which have been evolved and perfected, and the advances in fundamental science which have made them possible. The other series will survey the tools of industrial chemistry to-day, and cover such subjects as modern manufacturing techniques and the use of metals and non-metals in plant construction.

Use and Welding of Aluminium in Shipbuilding

ON Wednesday, December 7th, and Thursday, December 8th, a symposium on the Use and Welding of Aluminium in Shipbuilding was held at the Institution of Civil Engineers, Great George Street, Westminster, S.W.1. The symposium, which was divided into four sessions, was organised jointly by the Institute of Welding, the British Welding Research Association, the Institution of Naval Architects, the British Shipbuilding Research Association and the Aluminium Development Association.

At the first session on Wednesday morning, with Sir Charles Lillicrap in the chair, five papers relating to welding process and techniques were read and discussed. In the first paper, "The Selection and Use of Processes for Welding Aluminium," P. T. Houldcroft, B.Sc., discussed the factors to be considered before choosing a welding process for the fabrication of a component and various welding processes, particular attention being paid to the welding of superstructures. The advantages and disadvantages of the inert gas self-adjusting-arc process and the coated electrode metal-arc process for structural welding were examined and guidance given on the question of edge preparation. "Recent Developments in the Metal-Arc Welding of Aluminium Alloys in Great Britain" was the title of the second paper, by W. I. Pumphrey, M.Sc., Ph.D., in which the developments in metal-arc welding were noted, together with the fact that an electrode with a high silicon content had been produced to counter the ill-effects of excessive weld dilution when H.10 material is welded at high current densities. Tables giving examples of metal-arc welded joints and the tensile properties of metal-arc butt welds were included, and it was stated that a technique had been devised for welding aluminium to steel.

The third paper, "Process Variables and Porosity in Self-Adjusting Arc Welding," by P. T. Houldcroft, B.Sc., and A. A. Smith, B.Sc., considered the sources of porosity, process characteristics, the effect of arc length on porosity and the influence of variations in welding technique on its occurrence and severity. A. E. S. Rogers was the author of the next paper, "Inspection and Control of Weld Quality in Aluminium Structures." The paper discussed the various factors governing the production of sound welds and the importance of design and welding procedures in minimising the need for repairs. The desirability of having competent examiners was stressed and notes given upon the importance of storage and preparation of the material in the production of good welds. Radiography was recommended as the most suitable method of non-destructive testing and the production of satisfactory standards was stated to be in hand. J. E. Tomlinson, B.Sc., and J. G. Young, B.Sc., presented the paper "Inspection and Control of Quality in the Inert-Gas Welding of Aluminium and its Alloys," in which the selection and training of welding personnel were considered as a first step towards the control of weld quality. Factors influencing weld quality were outlined.

Materials and design provided the theme of five papers read at the afternoon session, under the chairmanship of R. B. Shepheard, C.B.E., B.Sc. The paper read by H. J. Adams, M.Sc., "Notes on Light Alloys in Shipbuilding," discussed the alloys from the point of view of Lloyd's Register of Shipping and gave a résumé of the requirements of the Society for plate, castings and rivets, followed by references to corrosion and fire resistance. "Welded Aluminium Alloy Structures: the Strength and Performance of Welded Joints and Their Influence on Design," was the title of the paper, submitted by C. P. Oldridge, R.C.N.C., which was mainly concerned with a full penetration butt weld joint made with the consumable electrode inert-gas-shielded process in 3–5½ per cent magnesium alloy sheet and plate. The results of tensile tests on a series of welded specimens were recorded and discussed as were those from certain bulge explosion experiments. Work on hydrostatically loaded panels of plating was described, followed by an assessment of the ability of aluminium alloy to absorb energy, as a criterion of design and there was a reference to fatigue which included fatigue curves for a number of specimens.

"The Selection of Filler Alloys for Welding Aluminium" was the title of the third paper, in which P. T. Houldcroft, B.Sc., and F. Fidgeon, B.Sc., reviewed the questions of the special composition of filler alloys and the effect dilution upon the composition of the weld bead and the strength and cracking resistance of the joint. There was particular reference to the welding of the heat-treatable aluminium-magnesium-silicon alloy H.10, and tables gave the tensile strength of butt welds in the material, made by the self-adjusting arc process, and the effect of filler composition on the cracking of H.10 welds. N. V. Almy, in his paper, "Mechanical Strength of Welded Joints in Aluminium Alloy Plating," described a series of strength tests on welded butt and fillet joints in NP5/6 plating, ranging from ⅛in to ¼in thick, using both argon arc and self-adjusting arc methods. A number of tables recorded the results and indicated that the butt joints showed efficiencies ranging from 88 to 100 per cent, based on the annealed strength of the parent metal, while the shear strength ranged from 7·3 tons to 12·4 tons per square inch, depending upon welding method and direction of loading. The final paper read on Wednesday, was "The Testing of Welded Aluminium Structures," by A. M. Mackie, B.Sc., and gave a brief account of present-day structural testing followed by a description of the test equipment at Aluminium Laboratories, Ltd. Examples of test rigs for various ship structures were illustrated and from such structures it was concluded that fillet welds connecting stiffeners to plating would not often be fully stressed. Test results on a welded Pratt truss, it was revealed in the paper, demonstrated the inadvisability of using the self-adjusting arc process for very short, fully stressed, welds.

The symposium was continued on Thursday morning with R. C. Thompson, C.B.E., M.A., in the chair, when six papers upon applications were presented. The first paper was "Scandinavian Experience with Metal-Arc Welding of Aluminium in Shipbuilding," by Arne Brinck, B.Sc., and it stated that metal-arc welding had been carried out on a large scale in Norwegian shipyards since the war. Mechanical properties of welded material was 65–70 per cent of unwelded material, which compared favourably with the strength of a riveted joint, and it was claimed that experience had shown that corrosion troubles were not to be feared. Tables in the paper gave the chemical analysis of electrodes, mechanical properties of welded and unwelded material, the results of corrosion tests, recommended currents, and gaps associated with electrode diameter and plating thickness. Welding procedure was detailed for the joining of plates, the attachment of stiffeners and the prefabrication of panels.

"Dimensioning of Light Alloy Structures" was the title of the paper by Professor H. E. Jaeger giving the bases upon which comparative strength calculations between steel and aluminium alloy structures may be made. A subdivision of structures into three groups was put forward with indications as to which ones are amenable to direct strength calculations and which to comparative strength calculation. What has been done towards fixing dimensions was surveyed and the requirements for aluminium alloy deckhouse plating and deckhouses from a number of sources were given in tabular form. Pierre L. Vidal presented the next paper, which was "The Construction of Light Alloy Superstructures for the Liners 'Flandre' and 'Antilles.'" It was revealed that 180 tons of light alloys were worked into each ship and that riveting was the method of joining. The paper went on to describe the arrangements adopted for the various parts of the structure and summarised the applications of the light alloys and their specifications, while appendices gave the composition and properties of the French aluminium alloys and details of the riveting.

In a paper entitled "Some Case Histories of Aluminium Alloy Small-craft" H. Goodwin traced the development of aluminium alloy small craft from 1929 and presented case histories of eleven vessels typical of the range of craft built including dinghies, canoes, lifeboats, sailing and motor yachts. Attention was drawn to certain precautions which should be observed during building to ensure satisfactory service. W. H. Dann, M.B.E., B.Sc., Wh.Sc., was the author of the next paper, "The Welding of Small Marine Craft in Aluminium Alloy," which referred to the considerations that led to the introduction of welding in the construction of light alloy small craft. The projects undertaken in Canada, U.S.A., and the United Kingdom were reviewed and a drawing given of the structural cross-section of an all-welded fast patrol boat, together with three diagrams, one giving symbols for representation of all types of weld, a second giving the specification of conditions of welding and the third setting out the welding sequence for frames. The paper was concluded with a brief outline of future developments and requirements. The sixth paper, by E. C. Goldsworthy, was entitled "Aluminium Alloys in Ships' Auxiliary Equipment and Fittings," and dealt with some of the numerous applications of aluminium alloys to parts of a ship.

Sir Victor Shepheard, K.C.B., occupied the chair at the fourth session, when applications and economic factors formed the main subject matter of the papers presented. A. R. C. Paterson gave the first paper, entitled "All-Welded Aluminium Deckhouse," which described the preliminary tests made before commencing the actual deckhouse which would be subjected to gun blast in service. Details of the preparation, method of erection and welding were given and also a résumé of the difficulties experienced. In the next paper, read by W. G. Warren, R.C.N.C., and entitled "Aluminium Alloys in Warship Construction," the early applications of aluminium alloys were reviewed and subsequent development discussed with particular reference to modern practice.

The paper by W. Muckle, M.Sc., Ph.D., "The Economics of the Use of Aluminium in Ships" commented that the use of new materials must be justified economically and that advanced methods of structural design and of construction should be used if they reduced first cost. The effect of the new aluminium alloy sections was referred to as was the question of upkeep and this was followed by a general survey of the economic position with reference to the cargo ship and the passenger liner. It was pointed out that use of the alloys may increase deadweight or reduce fuel consumption and that the latter would be the more profitable particularly for cross channel ships and Atlantic liners. J. G. Young, B.Sc., and J. E. Tomlinson, B.Sc., presented the next paper, "The Influence of Fabricating Methods on the Cost and Quality of Welding," which compared the various welding processes used for structural work on the basis of direct cost of operation and the results, presented in tabular form, showed that the self-adjusting-arc process was the cheapest and the fastest method. The general rules affecting the economics of the argon shielded-arc processes were discussed followed by detailed assessments of joint-making techniques for the self-adjusting-arc method. Advantages resulting from automatic welding were emphasised and its application in alternative schemes of construction were examined. The final paper of the symposium "Aluminium Alloy Materials—Economic and other Considerations in the Design of Two Types of Ship," was given by J. Lenaghan. After remarking that the relationship between steel and light alloys in ship construction was complicated, the paper noted that the technical problems associated with the lighter material were being gradually surmounted. Figures were given indicating the effect of substituting aluminium alloy for steel in an ore carrier and in a passenger liner and it was pointed out that although the economic aspect was not necessarily the deciding factor nevertheless the permanent use of material other than steel must be achieved on an economic basis rather than on purely technical progress.

Heat Treatment Furnaces for Gears

NEW electric furnace equipment for the heat treatment of gear wheels has recently been designed and built by The General Electric Company, Ltd., for installation at the Elswick and Scotswood works of Vickers-Armstrongs (Engineers), Ltd. The equipment includes two batch furnaces, with separate cooling chambers, for gas carburising the gear wheels, and a continuous hardening furnace. In the batch furnaces the processing atmospheres are generated from a special fluid introduced by a drip feed technique.

One of the carburising furnaces with its cooling furnace in the foreground can be seen in Fig. 1, below. These carburising furnaces are of similar construction and each is supplied with a set of three baskets for carrying the charges, and the baskets are 25in diameter by 36in deep. A heat resisting steel lining inside the furnace is supported by a wide flange and is free to expand at the base with rising temperature. A sand channel arranged round the periphery of the chamber provides a gas tight seal for the furnace lid, and the bottom of the chamber extends into an oil sealing trough. The lid, which is lined on the inside with heat-resisting steel plate, is supported through a pillar at its centre by a swivelling column on which it can be swung completely clear of the furnace during the work loading and unloading operations. The weight of the lid is partly taken when in the open position by a heavy laminated spring on the top of the column arm, and it is closed and held firmly on the sand seal by operation of a lever ratchet mechanism on its pillar. The lid can be rotated on its supporting pillar by means of tommy bars when it is closed to bed it down in the sand seal.

To produce the required atmosphere in the furnaces, carburising fluid is pumped to each from its own storage tank through an inlet in the lid at a precisely controlled rate. This liquid drops on to a hot plate in the furnace chamber where it volatises to produce the atmosphere. The atmosphere generated is circulated rapidly round the charge by a centrifugal impeller situated beneath the stool which carries the basket. For this class of work the G.E.C. has devised a cheap effective liquid consisting of three parts of methyl alcohol and one part benzene. The methyl alcohol acts as a carrier in the same way as does the endothermic gas in the other system of gas carburising.

The furnace elements are of heavy-gauge nickel-chrome ribbon carried on the inner furnace lining and protected by the steel lining or chamber from the carburising atmosphere. Each furnace has a maximum rating of 90kW. The cooling chambers are of the same size and shape as the furnace chambers and are sealed in the same way with lifting and swinging lids engaging in sand channels. For partially cooling the gear wheels before transferring them to a cooling chamber, air can be admitted through port holes in the lower part of the furnace walls and allowed to circulate round the outside of the carburising chamber. The gears are supported for carburising on suitable jigs such as that shown in Fig. 3 to minimise or eliminate distortion before being placed in the furnace baskets.

The carburised gear wheels are subsequently case hardened by heating in the roller hearth furnace (Fig. 2) and quenching in oil under a press. The gears are inserted into the furnace on trays and are moved continuously along by the rollers which are driven by an induction motor through reduction gears. The time taken for the gears to pass through the furnace can be varied from 31 to 155 minutes, the actual time being shown on a tachometer mounted near the drive unit. As a charge approaches the exit end it breaks a beam of light falling upon a photo-electric cell and an alarm bell rings to warn the operator that a charge is ready to be removed.

Fig. 1—Gas carburising furnace and cooling chamber of gear heat-treatment installation. The processing atmosphere in this furnace is generated from a fluid introduced by drip feed

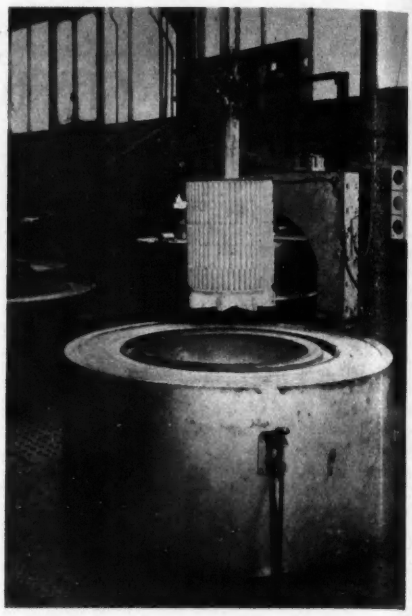


Fig. 3—Batch of gear wheels mounted in a jig being removed from carburising furnace

The doors at both ends of the furnace are suitably counterbalanced and are operated hydraulically with foot controls. Cradles and idle rollers are provided at the loading and unloading stations of the furnace to facilitate handling of the parts. The furnace has a heated length of 15ft and a maximum rating of 100kW. Its elements of heavy gauge nickel-chrome ribbon mounted in the roof and in the hearth are arranged in two independently controlled zones.

During the time that the gears are in the furnace they are protected from scaling by an atmosphere generated from fluid stored in containers above the level of the furnace and introduced by drip feed through inlets in the roof. The atmosphere problem is similar in both the carburising and the hardening furnaces in so far as it has to be in balance with a known carbon content. The temperatures of treatment are different, but this is compensated for by the fact that the gas carburising furnaces are efficiently sealed whilst the hardening furnace doors are repeatedly opened. The maker states that it is unusual for a continuous furnace to use an atmosphere generated internally from a fluid, but it has proved to be satisfactory in this instance.

Both the gas carburising furnaces and the roller hearth furnace are fitted with automatic temperature control and recording gear designed to provide temperatures up to 1000 deg. Cent.

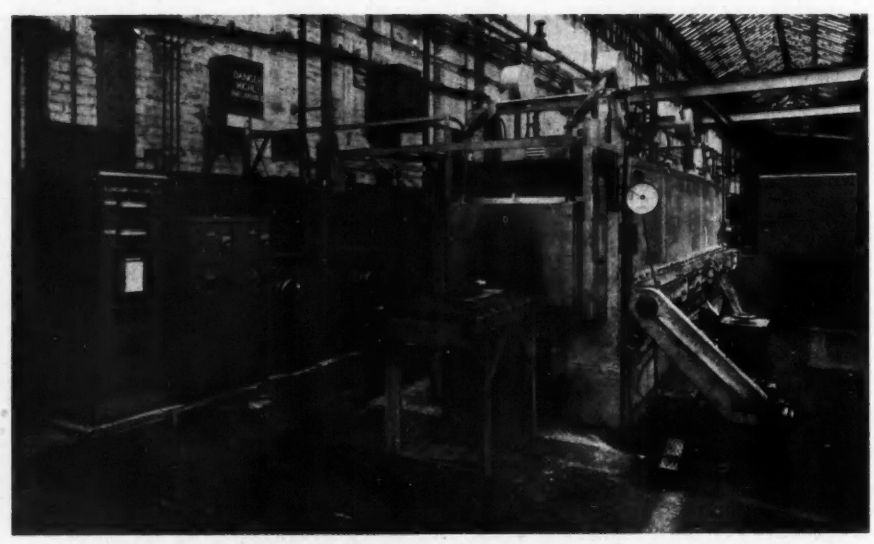


Fig. 2—Continuous roller hearth furnace used for gear heat-treatment

Electrical Equipment of a Sulphuric Acid and Cement Factory

A new plant has been completed for the production of sulphuric acid and cement by Solway Chemicals, Ltd., at Whitehaven, Cumberland. The production of these two related commodities forms part of what is in effect a continuous co-ordinated process, making extensive use of electrical drives. This article contains a brief description of some of the electrical plant.

THE sulphuric acid and cement producing plant of Solway Chemicals, Ltd., at Whitehaven, Cumberland, consists, in effect, of six sections: the raw material mines, the crushing plant, the mixing plant, the two processing sections—one for cement and the other for acid—and, finally, the facilities provided for the storage and shipment of the finished products.

The basic material in the process, anhydrite, is mined on site. Having been brought to the surface, this material undergoes two stages of crushing and is then mixed in accurately weighed proportions with shale and coke, the former also being mined on site and the latter obtained locally. After a careful drying process, the mixture is conveyed to the grinding mill house, where it is reduced to a very fine powder and then pumped into storage silos. Next the mixture is roasted in a coal-fired rotary kiln at temperatures in the region of 1400 deg. Cent. This roasting results in the production of gases containing sulphur dioxide and anhydrite clinker. After roasting, the sulphur dioxide is drawn through the kiln and the remainder of the acid plant by means of turbo-blowers; in passing through this part of the plant purification of the gas, conversion to sulphur trioxide and absorption of this in water to form sulphuric acid take place in succession.

Meanwhile the production of cement goes on as a separate process. After the cement clinker is taken from the kiln it is conveyed to the clinker building and there it is mixed with gypsum and ground to form cement. From the clinker building it is then "pumped" to the cement packing building, where it is automatically bagged ready for distribution by the Cement Marketing Board.

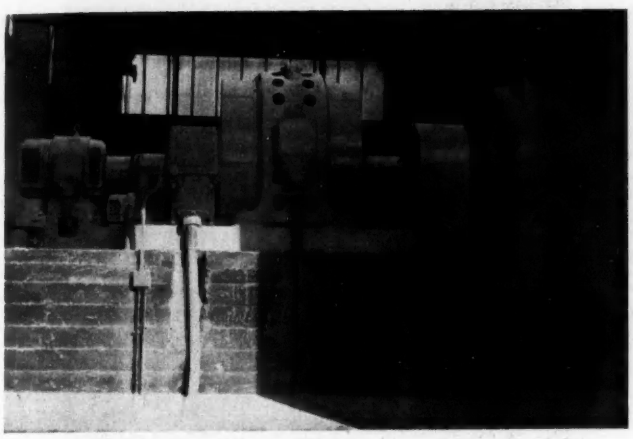


Fig. 1—850 h.p., 750 r.p.m., auto-synchronous motor for driving one of the raw meal grinding mills. Capacitors are provided to improve the power factor during the day when the grinding mills are shut down

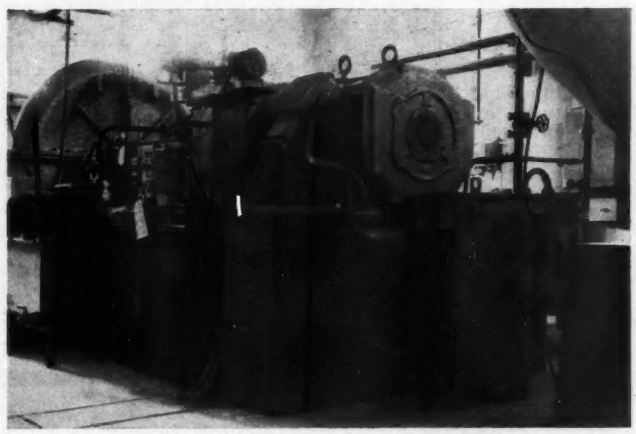


Fig. 2—400 h.p. induction motor driving a blower in the process plant. It has a double-cage rotor giving 40 per cent of full load torque at starting, with 3·5 times full load current. A capacitor for power factor correction is on the right

The Electrical Services

To ensure maximum continuity of supply it was decided to install an 11kV ring main system connected to a North Western Electricity Board's 33kV line already running alongside the site. Five main substations were built as part of the ring main system and were positioned at the main concentrations of load. But as the mine and crushing plant had to be located in the extreme south-western corner of the site it was found necessary to exclude them from the ring main and to build another substation separately fed from the main incoming substation through two 11kV duplicate feeders, using 0·2 square inch cable. This substation controls supplies to the preparation and handling plant for the raw materials, as well as to the mine and crushing plant.

The ring main cable is of 0·3 square inch section, a size that was selected to provide adequate capacity for the envisaged plant's load and for any future extensions. The choice of a liberally sized cable has already been justified in that the present output of the plant is 100,000 tons of cement and 100,000 tons of acid per year—30,000 tons of each product more than the original estimated output. The only modification to the distribution system that was necessary to meet the extra electrical load was the provision of a 3·3kV supply for the larger grinding mill motors (850 h.p. each) that were required. Apart from the grinding mill motors, practically all other equipment is supplied at 440V.

Originally a proposal was considered for the ring main to be erected overhead so that the possibility of acid attack on cables installed below ground could be avoided. This proposal, however, was rejected because the overhead system would have been vulnerable to damage while the plant was under construction. Accordingly it was decided to install the ring main underground. In areas where it had to be routed through the acid section and under roads and railways, it was piped. Further precautions were taken in such areas to guard against damage due to possible acid seepage, and an overall protective sheathing for the cable was provided as standard for the complete installation.

Special precautions were taken against the effects of acid fumes in the atmosphere: all outdoor transformers were hermetically sealed—instead of being provided with conservators—and the tanks were finished with an anti-sulphuric acid paint. Only two standard sizes of power transformers were used (750kVA for the 3·3kV supplies and 1000kVA for the 440V supplies) to facilitate interchangeability.

Switchgear, all of which is housed in standard brick and concrete buildings, was also standardised. All h.v. switchgear is Crompton Parkinson vertical-isolation "ALA" oil circuit breakers with air-insulated busbars suitable for fault levels of 150MVA, while the 3·3kV and low-voltage switchgear is of the same company's "Klad" design, except for a number of the ring main controls for which "ASA" isolators have been employed. Electro-tinning of copper busbars and connections was made standard procedure, but where the bare copper could not be tinned it was coated with an anti-acid varnish, except, of course, where such components were immersed in oil. Similar precautions were taken with the cable installation. All the paper insulated cables for h.v. and l.v. distribution are of Crompton Parkinson manufacture and incorporate a specially designed anti-corrosive covering to protect the armour and lead sheathing from the deleterious action which might follow as a result of possible acid seepage. Special precautions, moreover, were also taken at the jointing positions.

As it was intended from the outset that the ring main should operate "open," non-directional inverse-time relays "T.J.X." were preferred to pilot protection. The Reyrolle "T.J.X." relays were time-graded in collaboration with the North Western Electricity Board, which has similar relays in the main incoming substation.

Solenoid operation is used for the 11kV oil circuit breakers for the grinding mill so that distribution efficiency may be improved, bearing in mind that the mills are not running continuously. The 3·3kV and 440V switchboards are made up of "Klad" oil circuit breakers, while the oil circuit breakers for the 400 h.p. blower motors are arranged for solenoid operation, thus dispensing with additional starters. All these switchboard units are fitted with appropriate overcurrent and earth leakage protection.

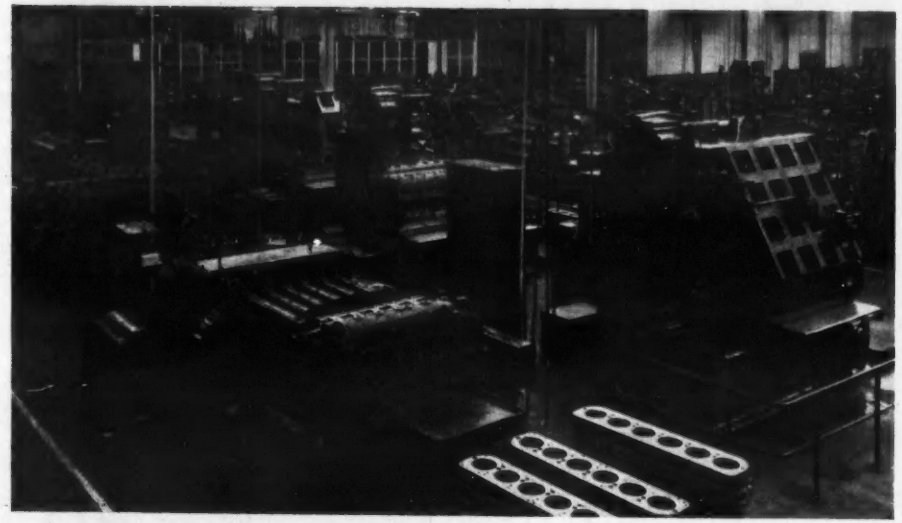
A total of 437 Crompton Parkinson motors, ranging from 850 h.p. to fractional horsepower, have been installed so far. It was originally planned that the three 850 h.p. grinding mill motors (Fig. 1) should be auto-synchronous machines with a leading power factor of 0·9 to correct the power factor of the complete system to better than 0·9 lagging. More recently, because of an attractive tariff from the N.W.E.B. for off-peak grinding, some 550kVA of B.I. Callender's static power factor equipment has also been added to achieve the obligatory power factor of 0·9 during daytime operation when the grinding mills are shut down. Another step taken to ensure that the plant is operated economically is the provision of metering equipment on each transformer and also on the mine system for cost calculation purposes.

The main drive in the acid processing is provided by three "N" type, 400 h.p. induction motors (Fig. 2). These machines are designed to develop 40 per cent of full-load torque at starting, with three-and-a-half times full-load current, by the use of double cage rotors. They are started direct-on-line by 1000A solenoid-operated "Klad" switchgear in one of the substations and are remotely controlled by push button at the motors.

The Fuller Kenyon air compressors used for pumping the anhydrite and cement are driven by slipring motors designed to produce 250 per cent full-load torque so that the plant can be started up with the pipes full.

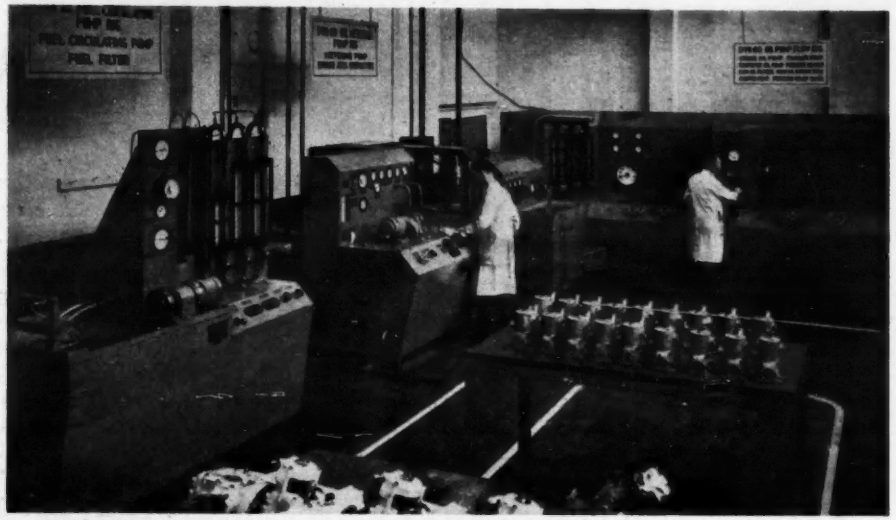
Motor starting is standardised throughout the plant; wherever possible the motors are started

MANUFACTURE OF THE "DELTIC" ENGINE



Part of heavy machine shop showing fine borers for machining six-cylinder liners in one operation; at the rear is a group of "Jigmills" machining the cylinder blocks

Drilling and heavy machine lines; in the foreground on the right is a special purpose multi-spindle machine with six index positions. On the left is a "Hydrotel" finish milling a cylinder block face



Test shop with equipment for flow and pressure testing fuel circulating pumps and fuel filters, testing metering pump for supply of oil to the scavenge blower and calibrating sparge jets

Part of the assembly shop with phasing gears being assembled in foreground and engines being assembled on revolving cradles at the rear

by oil immersed, hand-operated starters made by George Ellison, Ltd.; the liquid resistance and automatic starters were made by Allen West, Ltd., Brighton.

Much of the processing plant is in the open and a large part of the artificial lighting is effected by Crompton 250W mercury vapour lamps fitted in "Leo" type lanterns. These are mounted either on conventional street lighting concrete columns or on the steel supporting structures of the plant. Tungsten filament lighting is used for the remainder of the plant.

The fundamental design of the complete electrical installation has required very little alteration since it was first planned in 1952, despite the fact that the increases in plant output have entailed a considerable amount of extra electrical load. From the records taken so far it would appear that the maximum demand will remain in the region of 3750kW. The average power factor has been calculated to be 0·93 lag with a load factor of 59·6 per cent.

The design, installation and commissioning of the complete electrification scheme was the responsibility of Crompton Parkinson, Ltd., in collaboration with Marchon Products, Ltd. (the parent firm of Solway Chemical, Ltd.), who acted as the main contractor.

Manufacture of the "Deltic" Engine

LAST week, D. Napier and Son, Ltd., organised a press visit to its works at Liverpool to show the production lines which have been laid down for the manufacture of the "Deltic" engine. These engines are at present being made in two models with nine and eighteen cylinders for marine and industrial purposes and with outputs ranging from 825 to 2500 h.p. The eighteen cylinder 2500 h.p. high speed engine, which has been standardised for use in many navies, was described in our issue of April 24, 1953, and in our issue of November 4th last, we described the 3300 h.p. diesel electric locomotive fitted with two "Deltic" engines now in service on British Railways. For this locomotive two of the marine engines were down-rated from 2500 h.p. to about 1700 h.p. The particularly compact design of these engines makes them well suited to many applications and we understand that development in hand will lead to new ratings.

In laying down the machine lines and tooling up for the production of these engines, particular emphasis was placed on precision, not only to ensure ease of assembly, but also to give complete interchangeability of both the major units and the subsidiary components, which is necessary under the makers' "repair by replacement" policy. Some illustrations of the machine lines, assembling and test sections for the engines are given opposite.

Practically all the machines used are of standard designs adapted by jigs and fixtures for the special class of production. The main parts are made in batches and for this reason a number of the machines are quickly adaptable for machining different components by simply changing over the main holding fixtures to which subsidiary jigs are attached. This avoids the need for designing and building special machines at the outset, and facilitates the introduction of modifications which can be effected economically and relatively quickly by changing the necessary jigs. This practice is particularly noticeable in the drilling lines where a large number of radial drills are employed. In some cases a radial drill is set in the centre to work over up to four jigs, and in others a large indexing fixture is set at the side and used with supplementary jigs to drill, ream face, counterbore, &c., all the holes round a casing. The cylinder blocks are machined on the line of standard De Vlieg "Jigmills" situated at the rear of the special Heald cylinder liner fine boring machines in one of our illustrations. A large number of gears are used in "Deltic" engines and it is the practice to grind the highly stressed gears only on the flanks. It was interesting to note in the gear production line that it is the practice to finish the roots of the teeth on vertical broaching machines after cutting.

A special test shop has been laid down for testing and calibrating the oil pumps, fuel pumps, injectors, &c., used on the engine. Some of the rigs used in this shop can be seen in one of our illustrations. The fuel injection pumps are supplied as calibrated units locked to a given setting. One of the rigs in the shops is used for phasing and balancing the complete unit assembly mounted on the cam shaft casing.

A corner of the main assembly shop is also illustrated, and here there can be seen some of the phasing gear assemblies in course of assembly. At the rear of this section there are some completed engines on their erection cradles on which they can be turned to any required angle to facilitate assembly. A particular advantage in assembling the engines is the relative lightness of the component parts, a majority of which can be fitted together and combined on the engine with the use of only light lifting tackle.

Basic Jet Trainer

A RECENT visit to Shoreham Airport, Sussex, enabled us to see, in the works of F. G. Miles, Ltd., the prototype of the M.100 "Student," an *ab initio* trainer intended to reproduce the flying characteristics of modern military aircraft. The aircraft is a shoulder wing monoplane, with the instructor and pupil seated side by side in the nose enjoying an excellent view forward. Immediately above and behind the wing the power unit is located, the air intake being recessed in the cabin roof where foreign bodies should not reach it, and a monococque after body of slender proportions supports a dihedral tailplane with end-plate fins and rudders. The wings are slightly swept back, the trailing edges being occupied by flaps and ailerons, and provision is made for wing-tip tanks. The structure is riveted up from light alloy sheet. Since the "Student" has been built by a small company it is likely to be adopted by countries without a highly developed aircraft industry.

Much of the detail design is distinctive and reflects the requirements of the instructional function. Maximum permitted airspeed for the machine is 460 m.p.h., and provision must be made for emergency exit at this speed. To avoid the cost and weight of ejection seats or an emergency drill involving inverting the aircraft, a door the size of that of a car is fitted each side of the cabin. When the door has been jettisoned, the pilot can throw himself down and sideways through the opening with no risk of hitting the wing. The cabin floor is only 18in from ground level; since it is entered from the side and not above, the control column is curved, as illustrated, to facilitate access. As in operational military aircraft, a tricycle undercarriage is provided. The provision of doors and large windows prevents the forward fuselage being of stressed skin construction, and a central keelson carries the nose wheel at its front end: this member will resist damage in a wheels-up landing or crash. The nose wheel can be steered from the rudder bars or left free to castor. The main undercarriage units retract into the fuselage behind the cabin, the geometry being similar to that of some amphibian aircraft in which it has been desired to keep the planing bottom unbroken. In effect, there are upper and lower wishbones, which when retracted come together in the vertical position with the suspension leg and wheel beside them in the fuselage. When the undercarriage is extended, the wishbones, each machined in one piece from light alloy, reach out and down through the sides of the fuselage, passing above the bottom longerons. The retracting jack is operated by compressed air from the engine; the initial movement in each direction serves to draw out of engagement the spring-loaded locking plunger. Behind the main wheel bay are pivoted sector-shaped flat plates that can be moved edgeways out of the fuselage by pneumatic rams to act as air brakes. The prototype has a single Turboméca "Marbore," but an alternative installation is two "Palas" units; the latter version is intended to allow relighting in flight, single-engine cruising, and other twin engine techniques to be exercised. Since both engines are very close to the aircraft centre line, rudder trim tabs are not provided; however, electrically operated tabs are fitted to the elevator and arranged to respond also to control movement in such a way as to give the feel of a heavier aircraft. The wing is swept with the same intention of simulating service aircraft.

One other requirement that has been treated as important is that a trainer should be cheap to build and operate. The Miles project will be a smaller and lighter machine than contemporary jet trainers, but, nevertheless, will be capable of weapons training and also, by adding two seats in the space behind the pilots normally allotted to the radio equipment, can become a communications aircraft. In service, maintenance should prove particularly easy: the engines are completely exposed on a flat platform at shoulder height when the cowling is removed. However, cheapness has not been obtained by any sacrifice of strength or life, the design factors being those ruling for Royal Air Force fighters. The builders believe that, while costing far less than a high-performance trainer, the "M.100" would emulate a service aircraft closely enough to show up unsuitable pupils in the early stages of training.

It is hoped to complete and fly the prototype in the first half of next year; it has been built purely as a private venture. Production aircraft would use Blackburn engines.

The large cockpit door can be jettisoned for emergency exit, by the handle showing just within the cabin. The control console is on top of the main structural member of the forward fuselage. The position of the leading edge can just be seen

Conference on Courses for Electrical Technicians

A CONFERENCE on courses for electrical technicians was held on December 2nd last at the Institution of Electrical Engineers, under the chairmanship of the president, Sir George H. Nelson, Bt. It was attended by principals of technical colleges, education and training officers in industry and representatives of the Ministry of Education, Regional Advisory Councils for Further Education, and the Services. It was the third conference to be convened by the council of the Institution since it first invited interested organisations in 1953 to consider the widespread need for more courses to cater for the large number of electrical technicians for whom the existing craft courses and National Certificate courses were not suitable. After the second conference, in July, 1954, an interim report was published by the Council and the City and Guilds of London Institute then undertook to develop a scheme of courses on the lines recommended in this report. The City and Guilds of London Institute have now drawn up regulations and syllabuses for the conduct of examinations for electrical technicians and the main object of the recent conference was to discuss its implementation. A short report on the new scheme has been published (price 1s.) by the Institution of Electrical Engineers, Savoy Place, London, W.C.2. The scheme will offer Technicians' Certificates for technicians engaged in the design, manufacture, testing, erection, operation and maintenance of electrical plant and equipment in many branches of electrical engineering. Initially the courses will cover plant and machinery, power generation and supply, and industrial electronics. Additional courses will be developed to meet other needs of the electrical engineering industry, and in response to a request by the council of the Institution early attention will be given to a course for electrical drawing-office technicians. The new course is of four years' duration and is intended for students attending part-time day classes for one day per week or for three evenings per week. The subjects of the first two years include electrical engineering principles, engineering materials and drawing, practical mathematics and technical reports. In the third and fourth years the course caters for the special requirements of technicians who will be employed on power equipment or in industrial electronics. In the fourth year provision is made for colleges to develop courses and examinations in a "special technique" according to local requirements. Endorsement courses in "special techniques" at a more advanced level may be provided for those who qualify for the Technicians' Certificate at the end of the fourth year. A Full Technological Certificate will be awarded to candidates who hold an Electrical Technicians' Certificate and subsequently obtain passes in at least two endorsement subjects. The Electrical Technicians' Certificates will be endorsed by the Institution of Electrical Engineers, the City and Guilds of London Institute and, when appropriate, an association concerned with technicians. The Full Technological Certificate will, in addition, be endorsed by the Ministry of Education. Full particulars of the courses and examinations are published by the City and Guilds of London Institute in Pamphlet No. 57, entitled "Electrical Technicians' Courses." The scheme was outlined at the conference by Mr. M. W. Humphrey Davies, chairman of the City and Guilds of London Institute committee responsible for the syllabus: he indicated that the new courses placed less emphasis on the mathematical and more on the practical aspects of electrical engineering and should appeal to the student who found the National Certificate course too difficult. Mr. C. Grad, education manager of the British Thomson-Houston Company, Ltd., spoke on behalf of industry and expressed its support for the courses. Dr. J. E. Richardson, Principal of the Northampton Polytechnic, and Dr. J. S. Tait, Principal of the Woolwich Polytechnic, discussed the problems of organisation and said that they expected to see a number of colleges offering the new courses in September, 1956. Dr. Willis Jackson, director of research and education, Metropolitan-Vickers Electrical Company, Ltd., spoke as the chairman of the committee which had prepared the Interim and Final Reports of the Council; emphasising points made by other speakers, he pointed out that National Certificate courses would remain as a route—though an arduous one—to professional status, while the Higher National Certificate in Electrical Engineering in its own right would continue as an appropriate qualification for many high-grade electrical technicians.

Mobile 3-Ton Crane

A NEW model which has been added to the range of mobile "Jones" cranes made by K. and L. Steelfounders and Engineers, Ltd., Letchworth, Herts, was demonstrated at the firm's works last week. The new crane, known as the KL33 model, has a maximum capacity of 3 tons at 7ft 6in radius and is designed to replace the KL22 model 2-ton capacity crane. It is a fully slewing machine capable of taking its maximum rated load without the use of outriggers, and has the same unit construction as the firm's other mobile cranes. With this form of construction each motion is designed as a totally enclosed, interchangeable unit, and direct mechanical transmission is used so that if necessary the full power of the diesel engine can be applied to any motion. All motions are independently operated and reversible, and any two can be operated simultaneously.

Four alternative arrangements are available for the drive of the wheeled chassis of the crane to suit it for different site conditions. A direct drive can be supplied for normal working conditions, whilst a two-wheel differential drive with lock gives increased manœuvrability when using the differential, with the advantages of the direct drive for soft or uneven ground work. A four-wheel differential drive gives a high performance over rough ground, without losing the speed characteristics. A two-wheel differential arrangement with four-wheel steering used with cranes working in restricted spaces and narrow gangways gives a turning radius of 13ft and retains the full stability of the four-wheel mounting.

A number of alternative jibs are available, and the maximum load can be lifted with either the standard 20ft channel jib or a 16ft 9in cantilever jib. Although all the motions can be operated in a ratio of 3 to 1 the crane is designed to work in high gear, medium or low gears only being required when it is travelling with a full load or negotiating gradients. The hoisting speeds are as follows: 1 ton on single fall of rope, 100ft per minute; 2 tons on two falls of rope, 50ft per minute; 3 tons on three falls of rope, 33ft per minute. Derricking from maximum to minimum radius takes seventeen seconds and slewing is effected at 3¼ r.p.m. The travelling speed with a load of 1 ton in high gear is 6 m.p.h.; with a 2-ton load in medium gear, 3 m.p.h.; and with a 3-ton load in low gear, 3 m.p.h.

The main chassis of the crane is a rigidly braced welded steel structure which carries the rotating superstructure on a large diameter ring of ball bearings located in grooves. Hook rollers operating on the underside of the cast steel slewing path secure the superstructure to the chassis. A Petter two cylinder diesel engine used to drive the crane develops 13·2 h.p. at 1800 r.p.m., and is available with either air or water cooling. From this engine power is transmitted through a friction plate clutch to a three-speed gearbox and on to a main roller chain drive. From this main drive power is transmitted through separate clutches to each crane motion.

3-ton crane with standard 20ft jib

In the winch motion a plate clutch provides smooth hoisting and two machined external shoes, applied by spring pressure, operate on a large brake drum to control the load when lowering. The brake drum is fitted with a silent pawl mechanism which engages the brake automatically as soon as the winch clutch control lever is released. A plate clutch is used for power lowering and the empty hook can be lowered at a speed of 160ft per minute. The 9½in diameter winch barrel is grooved to take ½in diameter preformed steel rope.

The superstructure can be rotated through a complete circle, the motion being transmitted through an independent unit, and operated through friction plate clutches controlled by a hand lever in the driver's cab. A friction brake holds the superstructure in any position until the slew control is operated. For the derrick motion, power is transmitted through large plate clutches, bevel and worm gearing. The derrick brake is fitted to the

worm shaft and is automatically applied when the derrick control lever is released.

The crane is mounted on four 7·50-20, heavy duty pneumatic tyres and steel restrictor wheels. Transmission is carried from the main drive through a flexible coupling to the totally enclosed travel motion gearbox, situated over the centre of rotation of the superstructure. Machine-cut bevel and spur gears transmit the power to the chassis through a vertical shaft. The direction of travel is effected by means of selector clutches controlled by a hand lever on the steering column. The wheels are all interchangeable and fitted with 14in diameter two-leading-shoe brakes, controlled by hand lever and pedal from the driver's cab.

The crane has automatically correcting steering so that, irrespective of the position of the superstructure on the chassis, steering direction is normal. The reversing equipment consists of a system of gears under the steering column and working in conjunction with a cam running on a path cast into the slewing ring on the chassis frame. The correcting action is obtained automatically by the cam operating a lever mechanism, which selects the appropriate gear in the reversing box. A chain drive and gear carry the steering motion to the worm box in the chassis and then to the wheels. For working in restricted spaces and narrow gangways, a two-wheel differential drive chassis can be fitted with four wheel steering.

The driver's cab on the right front of the superstructure has safety-glass windows all round and the roof is half glazed to give a good view of the load under all conditions. All the controls required to operate the crane are arranged in the most convenient manner for the driver to use without fatigue. A gravity operated radius-load indicator is fitted on the jib in front of the driver, and an automatic self-resetting derrick overwind limit gear is a standard fitting.

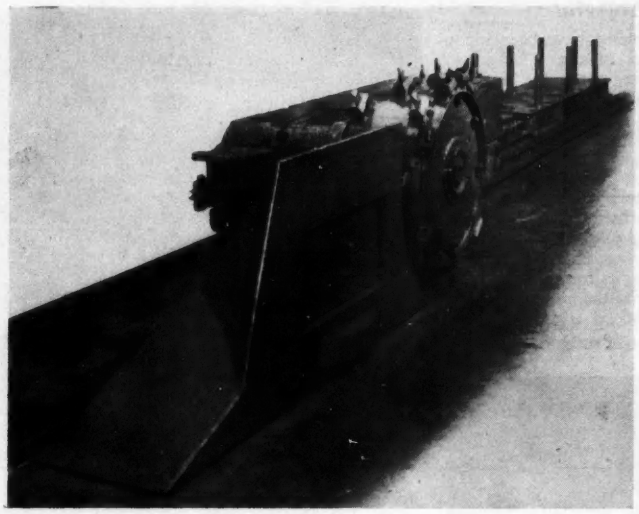
Coal Shearer-Loaders

A MACHINE now being made for coal cutting and loading by British Jeffrey Diamond, Ltd., Wakefield, is the shearer-loader we illustrate on this page. This machine is mounted on an armoured conveyor and as it moves along the coal face a revolving drum fitted with coal picks shears the coal which is transferred on to the conveyor belt by a plough behind the drum. When the machine is flitting back any coal in the path of the plough is swept up by a shoe at the rear of the plough and turned on to the belt.

The machine is fitted with a 75 h.p. one-hour rated squirrel-cage motor suitable for a three phase, 50 c/s supply and standard voltages used in mines. The motor stator is former-wound with B.S.I. class "B" insulated coils which are fully insulated before assembly into open slots which are finally closed by magnetisable wedges. The double-squirrel-cage motor has the outer cage immediately above the inner cage. The starting switch, housed in a side compartment cast integrally with the motor stator frame, is a three-phase reversing drum pilot switch for use with remote control, gate-end switches.

The shearing unit of the machine has two cast steel gearcases, one containing the first set of reduction gears and drive engaging device. The second, main, reduction gearcase is split in two halves and has removable cover plates to give easy access to the gears. There are four gear reductions, the first being a straight spur gear from the motor. The reduction pinion of the first gear is splined on the motor shaft and forms the means of engaging and disengaging the drive to the drum through the remaining spur reduction gears. Drive engagement control is effected from the goaf side of the machine only and the control handle is automatically locked when the gear is in the engaged or disengaged positions.

The shearing drum to which the steel pick holders are welded is keyed on the final reduction shaft of the reduction gearbox and secured by a retaining plate. Drums of different widths can be supplied with diameters from 32½in to 50in. The pick holders are generally arranged to maintain the cutter picks at right angles to the surface of the drum, and the outer rows are set at an angle to allow cutting clearance for the drum.



Coal shearer-loader with which coal is cut from the face by picks on a rotating drum and turned on to a conveyor by a plough

The mechanical haulage unit of the machine is housed in a steel casting and the operators' controls at the front end include a starting handwheel, slow haulage ratchet control, change gear handwheel, and water spray control valve. A continuous rope capstan drum below the controls has in front of it a brake control handle. The gears in the haulage transmission system are always in mesh. When the brake is applied the drive to the capstan is on the "fixed gearbox" principle so long as the rope pull on the drum is less than the braking effort. When the rope pull exceeds the braking effort the drum rotates round its internal gear until the rope pull falls below the predetermined level. A complete obstruction causes the drum to stop until the machine is clear, when the feed is automatically taken up again. This arrangement provides an automatic feed and safety measure whenever the predetermined rope pull is exceeded.

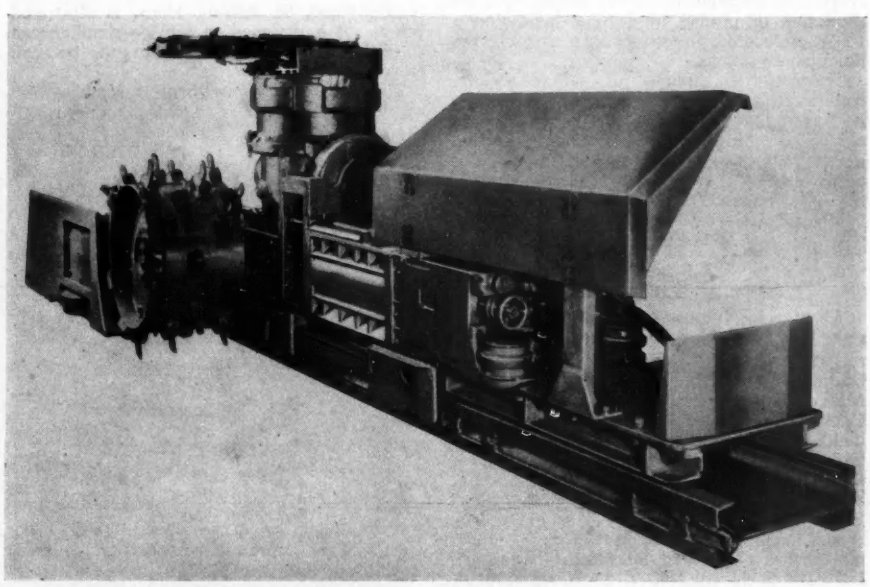
The machine has three shearing speeds which are available in three ranges, as follows: 21in, 42in and 63in per minute; 27in, 54in and 81in per minute; and 34in, 68in and 102in per minute. In these ranges the respective ploughing speeds are 30ft, 39ft and 49ft per minute.

The fabricated steel plough which adjoins the pick drum is so shaped that it turns the sheared coal on to the conveyor as the machine travels along the face. The rear end of this plough, as can be seen in the illustration, is formed as a wedge-shaped shoe, so that during flitting it sweeps up coal in the return path and deflects it on to the conveyor. Water for sprays is carried through a protected pipe along the length of the machine and taken through flexible tubes to the plough. The water is sprayed through four jets on the plough edge nearest to the pick-drum. A fabricated underframe extending from the shearer gearcase to the haulage unit is fitted with plates which keep the machine aligned on the conveyor.

Our second illustration shows one of the firm's ranging shearer-loaders. It has a ranging unit which forms an integral part of the shearing assembly. The same 75 h.p. motor drives both the shearing drum and the telescopic hydraulically operated turret and jib fitted with cutter chains and picks. This machine is designed for use in thick coal seams and it can be supplied with 32½in to 50in shearing drums. With its ranging head, seams from just under 5ft to 7ft 3in can be cut without the use of shot-firing.

Engineers' Stethoscope

WE have recently been able to try a mon-aural stethoscope supplied by the Capac Company, Ltd., 2, Ullswater Road, London, S.W.13. It consists of a metal earpiece containing a nickel silver diaphragm, to the antinode of which is screwed the first section of the listening rod. One section of the rod is short and thick to act as a handle. The instrument showed itself effective; for instance, a synchronous electric clock, normally on the threshold of audibility, could be heard with ease at the earpiece. The probe allows the internal vibration at any particular location in a machine to be isolated; unlike the bin-aural equipment, for factory use, of the same manufacturer, this stethoscope will not pick up air-borne noise. Intended for the personal tool kit, it is supplied in a durable box.



Ranging shearer-loader which is fitted with a telescopic hydraulically operated turret and jib. This machine can cut thick coal seams from 5ft to 7ft 3in

Profile Projector

A NUMBER of improvements have been incorporated in a new model of the "Enbeeco" profile projector now being made by Newbold and Bulford, Ltd., Enbeeco House, Roger Street, London, W.C.1. This new instrument, illustrated below, has an 8in by 7½in screen comprising two sheets of glass between which is placed a sheet of "Ethulon" plastic tracing film. An enlarged drawing of the profile to be checked is made on this film, the use of which obviates necessity for frosting the glass screen.

The work platform or stage is 5in long by 4in wide and is set at right angles to the optical axis of the projection lenses, and the image is thrown on the screen by aluminised surface mirrors.

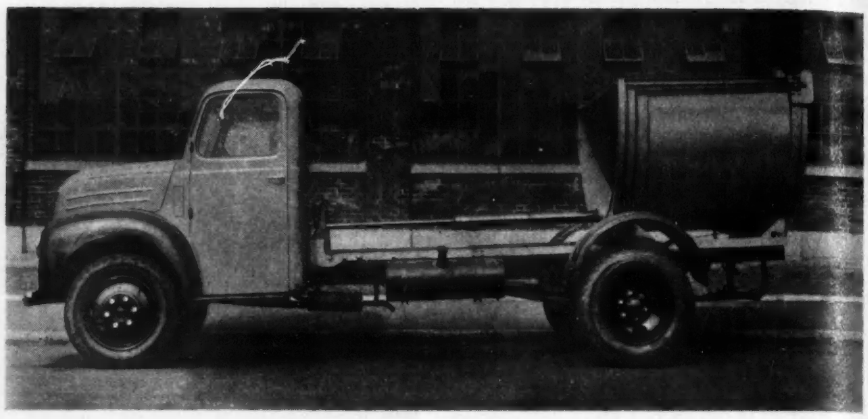
Improved profile projector with 8in by 7½in screen and projection lenses, giving ×10 and ×15 magnifications

Achromatic projection lenses giving magnifications of ×10 and ×15 are mounted in a slide and by simply operating this slide the required lens is selected quickly and easily. Objects up to ½in diameter are covered by the ×10 objective and up to ¼in diameter by the ×15 objective. A specially computed condenser ensures accurate projection of profiles by parallel light, and a 100W prefocused projection lamp provides the illumination source.

The platform is mounted on a screwed column incorporating means of vertical adjustment, and its longitudinal and transverse movements are controlled through ½in micrometers, giving direct readings to 0·001in or 0·020mm. Components up to 1¾in high can be accommodated for the ×10 magnification and up to 1½in for the ×15 magnification.

Special Lorry Bodies

AT Fleet, in Hampshire, County Commercial Cars, Ltd., recently extended the factory occupied on conversions of Fordson tractors to afford facilities for the other members of their group, Market Transport, Ltd., and Walkers and County Cars, Ltd. At the opening of the new building an exhibition was presented of the group's products. Besides various versions of the Fordson "Major," in which the whole weight is used for adhesion, "Jekta" bodies (THE ENGINEER, page 315, September 4, 1953) were shown, and also a range of meat-carrying vehicles modified and operated by Market Transport, Ltd., 166, Weir Road, S.W.12. In these bodies meat is slung from the roof of a closed van and not piled on the floor; each piece is hooked to a runner that can be drawn along rails in the roof



The body and the ram of the 6-cubic-yard "Jekta" have three elements

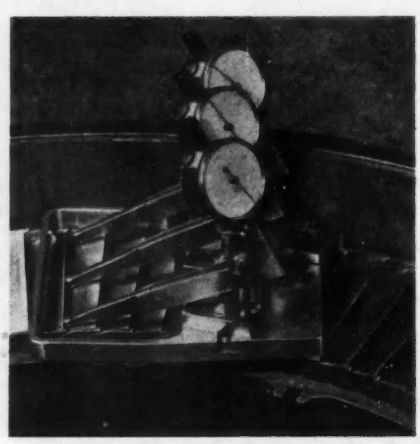
and settles into the cross piece of an arch pivoted at the tail of the vehicle. A hydraulic ram can raise or lower the arch, and in the lowered position the meat can be manhandled away. A film showed that, at an abattoir, meat could be brought to the vehicle by overhead rails, the hooks of the "Market Loader" engaged, and the meat lifted into the body and run forward with no manhandling. The bodies on display included a tall van on an Albion "Chieftain" chassis for handling sides of beef and a 7-ton refrigerated vehicle.

From the power loader of these vans there is being developed a Gantry Loader capable of lifting loads under a hook and placing them anywhere on a platform body. The prototype only was on view, intended for individual loads of 10 cwt to 30 cwt: it took the form of an arch or gantry raised by a single-acting ram and capable of being run to and fro on rails along the sides of the body of a Leyland "Hippo" by hand winding. The load is hitched directly to the arch and the lift available is slightly more than the loading height, so that the vehicle would normally be loaded from the front aft and unloaded in the reverse order. The easy handling of pallets or standard packages will be one of the targets of the development programme.

Diffuser Throat Checking Instrument

AN instrument for checking the throat area in the diffuser rings of jet turbine engines, which has been developed by British Indicators, Ltd., Sutton Road, St. Albans, Herts, is illustrated below. It is designed to provide simultaneous readings at three points in the gaps between adjacent blades.

The three measuring head assemblies are adjustably mounted on slotted columns, which



Instrument with three measuring heads for checking the throat area in diffuser rings

can be positioned across the base-plate in accordance with the points at which it is required to measure the throat gaps. The actual gauging heads are carried on pivoted arms so that they automatically register and enter the throat gap as the instrument is slid forwards. For the gauging operation the instrument is slid along on its base along the top of adjoining blades. As each measuring head operates independently, any rocking which may occur due to unevenness of the blade edge surfaces does not affect the accurate reading of the instument. An adjustable stop plate at one corner of the base is kept in contact with the shroud plate of the ring to ensure that the correct position of the gauge heads is maintained along the gaps. The minimum reading is taken from the dials as the instrument is withdrawn from a gap and the deviation from true size can be noted.

Demonstration of Sprayed Protective Coating

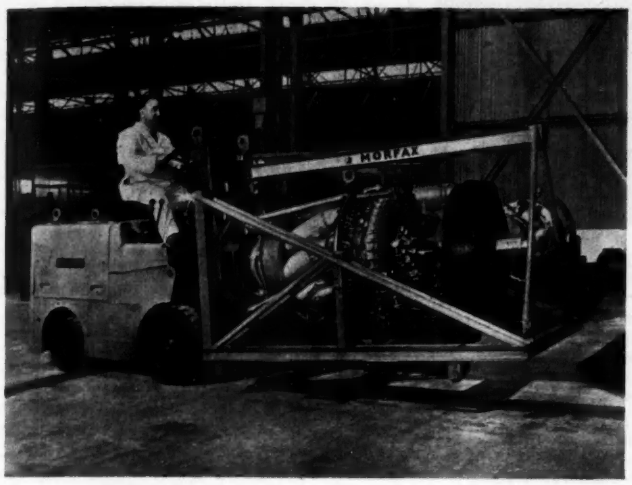
A PARTY of representatives from local authorities, public utility services, and industrial concerns recently attended demonstrations of metal and plastic flame spray coating at the works of the Schori Division of F. W. Berk and Co., Ltd., Brent Crescent, North Circular Road, London, N.W.10. In addition to manufacturing Schori spraying equipment and supplying the materials in powder form which are used in this process for applying protective or decorative coatings, the firm also provides a protective coating spraying service. Under this service parts can be treated either in the firm's own works, or, where large structures and parts are concerned, mobile plants are available to do the work on site. In the course of the demonstrations typical examples of component spray coating were shown in progress in the works using static plant, and in the adjoining works yard a mobile equipment was exhibited.

The Schori process of flame spraying can be used for applying protective coatings of zinc, aluminium, tin or lead; decorative coatings of copper, brass or bronze; hard facing with "Colmonoy," and building up worn parts with a variety of metals. Amongst the plastics which can be applied are polythene, nylon, shellac, "Araldite" and acrylic resins, and the firm has recently introduced a service and equipment for applying "Epikote" protective paints at its works or on site.

Another recent introduction by this firm is a process and plant for "peen" plating by which small metal parts can be plated without the use of electric current. Under this process the articles after cleaning are put into a hexagonal tumbling barrel with an impacting material, a promotor solution, the coating metal in the form of a fine dust and water. When the barrel is then rotated particles of the metal are welded on to the parts by the hammering action of the impacting material. With it zinc and cadmium coatings up to 0·002in thick, brass coatings up to 0·0002in thick, and tin coatings up to 0·0005in thick can be applied.

Transport Stand for "Dart" Gas Turbines

In view of the arduous conditions likely to be encountered in transit and the special nature of the "Dart" gas turbine engine, "Morfax," Ltd., of Willow Lane, Mitcham, Surrey, has, with the co-operation of Rolls-Royce, Ltd., Derby, constructed a transport stand which provides adequate protection for the engine and is suitable for both air and rail transport. The construction of this stand was desirable, of course, on account of the transport problem presented by such equipment as the "Dart" where the suspension pick-up points are at the rear. The stand, which is illustrated below, is specially designed for handling by fork truck as well as by the normal overhead lift. It



Gas turbine power plant mounted in special transport stand being handled by a fork-lift truck

has an all-up weight, together with a "Dart" engine, of approximately 2000 lb. The method of mounting the power plant is by cantilever support from the rear frame of the stand—utilising the engine "W" struts which pick up at four points—and by the port and starboard trunnion mounting points, which are secured between two hemispherical cups, thus leaving the propeller shaft entirely clear. To ensure interchangeability of power plants, the cups and their mountings have been designed with an appreciable amount of axial and lateral adjustment.

The stand can carry either a complete power plant, ready for installation into an airframe, or a bare engine. When transporting the engine alone the "W" struts are not fitted and therefore the four pick-up points normally used in conjunction with these struts cannot be employed. In this case, a single "V" strut is used which picks up the top trunnion ball on the engine and the top two mounting brackets on the rear frame. The side trunnion points are used as when transporting a power plant. The "V" strut is attached to the stand and can be readily removed when required.

Fitted to the stand by three points is the lifting beam which spans the engine lengthwise and affords a degree of protection along the top of the engine. This beam, which is hinged at the front, can be opened vertically to facilitate engine fitting or removal and can be removed entirely if necessary. Attached to the underside of the base of the stand are four bonded rubber-to-metal shock absorbers, which give a maximum vertical deflection of 2½in and are arranged to pick up the base bolts of the existing Rolls-Royce transportation box.

For lifting and loading purposes, a system of formed channels, suitably braced, running from front to rear and across the base of the stand, have been provided to permit handling by fork lift truck. Thus, lifting can be effected from both sides and the rear of the stand—the latter method being particularly suitable for loading into aircraft.

Floating Waterworks

By G. SMETHURST

At the Institution of Water Engineers' meeting on December 2nd, a paper entitled "Some Recent Works in Baghdad" was given by Mr. G. Smethurst. A general outline of the water supply installations in Baghdad which, the author considers, compare in standard with British practice, was given, and a number of recent improvement schemes described. One of these schemes, relating to floating purification plants, is described in the abstract from the paper which we print hereunder.

In connection with other work for the Baghdad and District Water Board, the author was obliged to make a journey by boat through the extensive marshes of Southern Iraq and, incidentally, to consider the possibility of building a waterworks at a small town called Chubayish. Chubayish is sometimes called "the Venice of Iraq," and although the similarity is rather far-fetched, there is at least a dearth of dry land. The author, with his mind full of floating pontoons (as constructed at Baghdad to carry low-lift pumps), considered the possibility of putting more and more of the works on to pontoons to be attractive. As there is literally no site for a high-level tank at Chubayish, the desirability of using pneumatic boosters, also pontoon-mounted, seemed obvious. Water engineers are always designing pontoons of sufficient strength to stop water bursting in, and sedimentation tanks sufficiently stiff to stop water bursting out.

The more one considered the matter, the more it seemed common sense to build the whole plant on a pontoon, as this would solve site conditions and, incidentally, to balance inward and outward pressures to the point where, theoretically, wafer-like walls would be sufficient. Over the next few weeks a design emerged, but other matters then intervened, and its adoption at Chubayish was delayed. In the course of its conception, the possibility of construction in plastic was considered, in view of the low stresses involved, and the point was referred to a large firm of manufacturers, for an opinion. When the opinion came it was not encouraging; but as the problems of Chubayish had temporarily passed away, interest in the "floating works" had passed also. At least, the interest of the author had temporarily waned; but at a later date the "Chubayish" design was in fact built, and is now being repeated in considerable numbers. The original installation is illustrated herewith.

Prototype Floating Water-Purification Plant

The water-purification plant comprises a series of welded units bolted together to form a compact vessel, on top of which a platform is mounted for carrying the ancillary equipment. The unit is moored to the river bank by an arm which is pivoted to allow a rise or fall according to changing river level. The mooring arm serves as a "cat-walk" to give access for routine maintenance, and can also carry the electric power cable aboard and the water delivery line ashore.

The unit is virtually a self-contained waterworks. River water is settled, filtered, chlorinated and delivered to the main at about 2400 g.p.h. against a head of 80ft. The cycle of operations is completely automatic; periodical cleaning of the filter is simple, as also is the disposal of sludge, &c., in the settling tanks.

There is a complete absence of filter controls, the flow through the filters being self-regulating by the variation of the water level in the purified-water tank. Because the unit floats, it is not affected by varying river levels, provided the river itself has the necessary depth for operation.

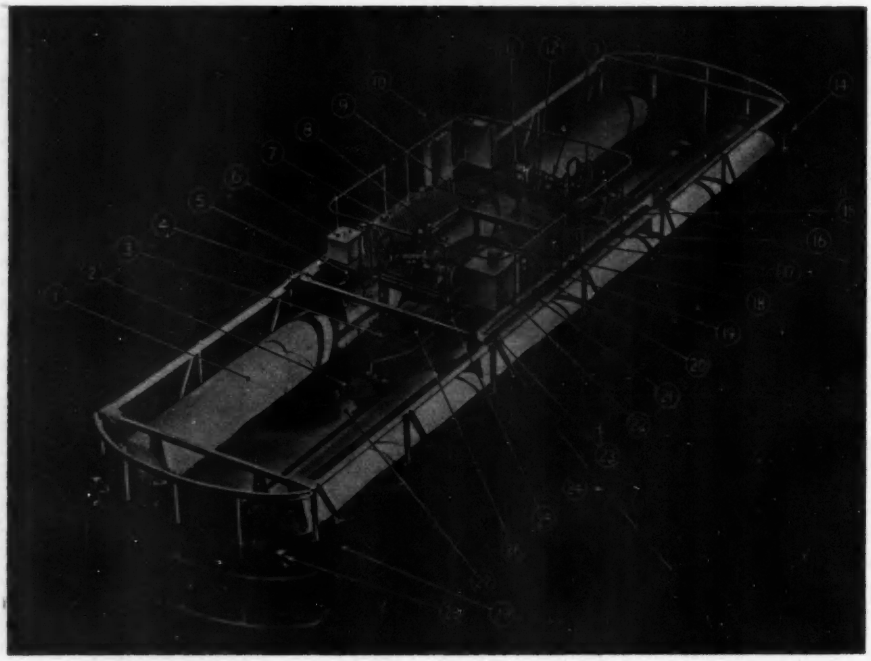
The plant is made in corrosion-resistant light alloy. It comprises several units of argon-arc welded construction, made in convenient sizes for transport and bolted together. The ancillary equipment, walk-way, handrails, and lifting and towing attachments are mainly in steel, protected against atmospheric corrosion.

The main component vessels of the plant—all fabricated in light alloy—are two rectangular-section sedimentation tanks; a cylindrical tank containing a filter bed; a purified-water tank, annular in plan, surrounding and integral with the filter bed; and two pneumatic booster tanks. There are eight buoyancy-tanks of two patterns, all rectangular in section.

The main ancillary equipment, comprising two water pumps, an alum-dosing pump, a chlorine-dosing pump, and an air compressor and associated electrical equipment, is carried on a steel platform on top of the unit. This platform is surrounded by a steel handrail.

The mooring arm is detachable, and is provided on site to suit local conditions; the arm used in the trials of the unit was 12ft long. The mooring system employs steel hawsers in tension, with the

First design of a floating waterworks shown in use at Latifiyah, Iraq



1—Buoyancy tanks (two).
2—Manhole to booster tank.
3—Purified water tank.
4—Mains outlet.
5—Mains outlet valve.
6—Chlorine solution container.
7—Wash water valve for general cleaning.
8—Chlorine dosing pumps.
9—Control valve—wash water to filter bed.
10—Electrical boxes.
11—Control valve—filter bed inlet.
12—Control valve—filter bed to purified water.
13—Water pumps (two).
14—River water inlet.
15—Air compressor.
16—Control valve—sedimentation tank air lift.
17—Control valve—sedimentation tank air lift.
18—Manhole to filter bed.
19—Alum dosing pumps.
20—Control valve—filter bed air cleaner.
21—Control valve—filter bed air lift.
22—Alum solution container.
23—Mooring and lifting shackles.
24—Mooring ropes.
25—Booster tank isolating valve.
26—Manhole to purified water tank.
27—Booster tanks (two).
28—Sedimentation tank air lift (two).
29—Sedimentation tanks (two).

Improved design of floating water purification plant. Several of these plants are under construction for use in Southern Iraq

mooring arm acting as a strut between the floating plant and the river bank.

The buoyancy tanks keep the vessel stable under all working conditions, including temporary superimposed loading.

The main structure of the unit is symmetrical. In the centre is the cylindrical filter-bed section, surrounded by the purified water tank occupying the annular space between two cylindrical tanks. At either end of the plant are the two pressurised booster tanks. Between these tanks are flat-sided sedimentation tanks, above which are fixed the four main external buoyancy-tanks ; inside the sedimentation tanks are four relatively small buoyancy-tanks. Over the main structure is a steelway deck, carrying the ancillary equipment.

Operation

In principle, the plant functions as a normal waterworks, purifying river water and delivering it to the mains at a suitable head. Dirty river-water enters No. 1 sedimentation tank through two 10in. dia. inlets, one on each side of the unit ; these inlets are always submerged below river level. After being dosed with an alum solution which causes the suspended sediment to flocculate and separate out, the water flows through transfer pipes to No. 2 sedimentation tank, on the other side of the central cylindrical tanks. The centrally-positioned purified-water section of the filter bed acts as a baffle. The water flows to the rear of No. 2 sedimentation tank, during which time the main deposition of flocculated sediment occurs.

The water then flows through a Y-shaped collector pipe to the filter bed, passing down through the filter bed into a collector pipe and thence into the annular purified-water tank. There it is treated with a chlorine solution, and this completes the purification process.

The purified water is then pumped by centrifugal pumps into the two booster tanks, against a pressure head provided by trapped compressed air. The booster tanks are both connected to the mains outlet.

The cycle of operations is automatic. When water is drawn off through the supply mains, the level in the booster tank falls, the compressed air above the water expands, and its pressure falls. The booster tanks are nominally pressurised to 30 lb per square inch gauge, and when the demand lowers the level of the water so that the pressure falls to 26 lb per square inch gauge, a pressure switch-relay-contactor starter arrangement " cuts in " the electricity supply and starts the pump motors. The pumps then transfer water from the purified-water tank to the booster tanks, until the water rises and compresses the trapped air to a pressure of 34 lb per square inch gauge. The pressure switch-relay-contactor starter then switches off the pump motors. Thus the operation of the pumps is automatic, as it is controlled by the rise and fall in booster air pressure, which is directly related to mains demand.

A difference of head between the water in the filter-bed tank (nominally at river level) and the level in the purified-water tank, brought about by pumping, causes the water to flow through the filter and so replenish the purified-water tank. The filtration process is therefore automatic, water flowing into the filter-bed tank from the sedimentation tanks under the hydrostatic head which is due to the difference in levels between the river and the filter tank. Alum-solution dosing and chlorine-solution dosing are carried out automatically, as the motor-driven dosing pumps work in conjunction with the water pumps. The output of the dosing pumps can be adjusted to give the correct dose for any condition, in relation to the solution strength used.

The settled sediment in the sedimentation tanks is periodically ejected by air lifts ; for this purpose compressed air, reduced in pressure to about 4 lb per square inch gauge, is utilised from the booster tanks. Air used in operating the air lifts is replenished by the compressor, which passes it directly to the booster tanks. Cleaning of the filter bed is carried out in the normal fashion.

The Ancillary Equipment

Pumps.—Two 1½in by 2in centrifugal pumps are provided to lift the water from the purified water tank and deliver it into the booster tanks. They are connected to work in tandem or (by use of the isolating valves and motor-starters) to work singly. Each pump is capable of delivering 20 g.p.m. against a gross head of 80ft at 2880 r.p.m. A direct drive is provided by two induction motors, totally enclosed, and continuously rated for 380V, 3-phase, 50 c/s a.c. supply. Their speed is 2880 r.p.m. and their brake horsepower 2·75.

Air Compressor.—One single-acting, single-stage, unjacketed air compressor is used to replenish compressed air which has either been used in air-lift operations or has become dissolved in the water. The compressor is capable of delivering 13/8 cubic feet of free air per minute against 40 lb per square inch gauge, at 700 r.p.m. The power absorbed is 3/8 b.h.p. A vee-belt driven, totally enclosed induction motor (continuously rated to develop ½ h.p. at 950 r.p.m., and using 380V-420V 3-phase, 50 c/s a.c. supply) provides the motive power.

Chemical Dosers.—Two metering pumps, one for alum solution and one for chlorine solution, are provided for the purification treatment of the river water. The pumps, of the adjustable-stroke type, are coupled together by a flexible coupling, and are driven through vee-belt by one induction motor, which is totally enclosed and fan cooled. The continuous rating is ¼ h.p. for 380V, 3-phase, 50 c/s a.c. supply. Both pumps incorporate loading valves on the delivery side.

The alum doser output, for 10 per cent alum solution, is 5 g.p.h. (maximum) ; the solution is contained in a 60 gallon glazed stoneware vessel.

The chlorine doser, for ½ per cent chlorine solution, has a maximum output of 2½ g.p.h., the chlorine solution being kept in a 10 gallon glazed stoneware vessel.

Electrical Equipment.—The automatic pressure switch cuts in at 26 lb per square inch and cuts out at 34 lb per square inch. It has single-pole contacts to operate the relay contacts. The relay is totally enclosed, and comprises operating coil and four contacts (normally open), to switch-in the motor-starters.

Transport Arrangements.—The whole plant is constructed of units bolted together, and can be dismantled to make components of comparatively small weight and volume, suitable for transport.

The two booster-tanks and the purified-water tank form separate sections ; and the eight buoyancy tanks are detachable. The sedimentation tanks can each be dismantled into four component sides, and the deck structure for the ancillaries can be taken apart. The ancillaries, handrail, and pipework can be packed conveniently.

Slinging points are provided on the ancillaries deck for hoisting the unit complete. For towing and mooring, shackles are provided on the sides of the vessel for the attachment of hawsers.

The net effect is that electric current passes on to the pontoon, and pure water under pressure comes out.

Improved Design

The Chubayish waterworks design was built with little modification and was duly put to work. Constructed throughout of aluminium alloy, it passed a series of tests and was installed at Latifiyah in 1955. In the course of development, however, it was observed that the original design was costly to build and that the clearance of silt from the sedimentation basins or the filter was not easy. Because the whole equipment floats on the river, the silt must be lifted, and for this purpose a system of air lifts was used. Effective as these were, the flat floor of the sedimentation basins and the low level of the filter interfered with fully efficient performance, and accordingly, the second model was redesigned with the following three objects in mind : (*a*) to simplify construction ; (*b*) to provide hopper bottoms in the sedimentation tanks ; and (*c*) to raise the working level of the filter.

The final design is illustrated above. This is the same design as that described, but modifications have radically altered the appearance. Several equipments of this kind are being built for operation in Southern Iraq.

Continental Engineering News

Scientific Recovery of Western Germany

A review recently published* describes the recovery which has taken place during the past ten years in West Germany's scientific activities, which were at a standstill at the close of the war. The report outlines the steps taken to rebuild laboratories, encourage the activities of learned societies, and bring scientific records and literature up to date. It was prepared by the United Kingdom Scientific Research Organisation, which was formerly part of the Control Commission.

The collapse of scientific and technological activity in Western Germany made it possible to rebuild the structure of its scientific and technical organisation on modern lines so that to-day the country has regained its former position in technology, although it still lags behind in those fields—aerodynamics, radar and nuclear science in particular—in which applied research was restricted or forbidden by post-war controls.

Industry has played its part in this reconstruction. It is estimated that the major chemical industries devote at least 5 per cent of their turnover to research, the corresponding figure for engineering undertakings being 1 per cent. Industrial firms are setting up their own research and development laboratories, e.g. one electrical firm has recently completed a research centre to accommodate 1200 research workers. Another undertaking constructed four large research laboratories in eighteen months. Industrial laboratories of this sort concern themselves not only with the day-to-day technical problems of industry, but also with programmes of fundamental research comparable with those carried out in more academic research centres. German industrialists keep in close personal touch with academic scientists and often employ them as advisers on technical problems. Many leading industrialists themselves regularly attend scientific gatherings and the larger industrial firms often employ panels of scientists.

As examples of the development carried out by the electrical industry may be mentioned the recent installation of two 150MVA turbo-generators with hydrogen cooling. Increasingly high voltages are being considered for overhead power transmission lines and research is now being carried out on the problems of establishing a European long-distance power supply circuit of 400kV. Work on electronics includes the study of radar techniques for use on road, rail and inland water transport, high-frequency, frequency-modulated radio systems and the production of electronic computers. One German firm has brought out a range of miniature low-tension accumulators, the smallest of which is a flat cylinder the diameter of a farthing. This accumulator is stated to have a capacity of 60mAh at 6mAh discharge rate. Portable receivers and deaf aids have been equipped with accumulators of this type, which can be recharged in ten hours either by a built-in power circuit or by means of a special small charger.

Among developments in transport in recent years are lightweight trains, one-third the weight of normal express trains, powered by diesel engines and capable of speeds up to 100 m.p.h., and double-purpose vehicles which are capable of travelling on rail tracks or on roads without delay in the changeover.

New ideas in rail transport include the use of high-pressure fuel gas as a propellant, and experimental work has been carried out on central beam monorail systems.

The possibilities of gas turbines as power units for heavy vehicles are being investigated, although it seems unlikely at present that they will prove economical. Improvements to diesel engines include noise reduction by means of a new combustion system and the use of catalytic equipment to remove odour and toxicity from diesel exhaust fumes.

A brake for motor vehicles, fitted in addition to the normal braking equipment, uses the compression pressure of the engine to provide braking power. It can be operated independently of the foot and hand brakes and, it is claimed, reduces the likelihood of skidding because the wheels are never locked and the system is independent of the brake linings.

The chemical industry is re-establishing its position, and its present level of production and export almost equals that of the United Kingdom. In all branches of the industry an extensive programme of building and equipping new research laboratories is being carried out. Among the many activities in this field are researches into synthetic fibres, detergents, pharmaceuticals, pesticides and vaccines.

Germany now claims second place in world plastics production and a new plastics research centre at Darmstadt is investigating the structure of plastics and the setting up of test methods. Among new plastics being produced are ethylene oxides with outstanding adhesive properties, particularly in the bonding of metals. Others are polyethylenes for pipework and unbreakable containers, glass fibre reinforced plastics for boat hulls and car bodies, and polymerisation products for foamed rubber and for floor coverings.

In the coal and gas industries new ideas for transport and storage are being used. A hydraulic pipeline is being used in the Essen area to convey 1000 tons of coal daily from coalfield to power station. Gas is being distributed from the Ruhr by means of a pipeline system 2000 miles in length. Experiments are being made in the underground storage of gas in natural formations in worked-out oilfields, a method which, if successful, will make possible great savings in the provision of gas storage facilities.

In common with other industrialised countries Western Germany is showing increasing interest in human relations, rationalisation and automation. Theoretical and practical psychological problems concerning fatigue, the fitting of the man to the job and the training of the various industrial groups are receiving attention. Although automation is only beginning to be introduced in Germany, automatic foundry processing has been adopted by one concern, and a well-known car manufacturer is producing 680 cars in a working day of seventeen hours by using centrally operated machines with automatic feed of material from one to the next.

Road-Rail Vehicle for Overhead Maintenance

In the accompanying illustration we show a road-rail vehicle specially equipped for the repair and maintenance of overhead electric wiring, particularly railway conductor wires. The design was developed by the S.N.C.F. and is based on a Renault van. Construction was carried out in the workshops of Billard et Cie, Tours.

By means of this vehicle it is possible to reach the neighbourhood of the point of damage by road, access to the railway being gained at a level crossing or station. The vehicle is placed across the track, and raised and turned until it is parallel to the rails by means of a hydraulically operated turntable fitted underneath. The same arrangement is used for a 180-deg. turn for reversing the direction of travel on rails. While the wheels are off the ground they can readily be changed in a few minutes. A set of five road wheels and four railway wheels is provided, the latter being fitted with rubber rings between wheel and tyre.

Converted from a standard design, this maintenance van has a hydraulically operated platform and reversing turntable and is equipped with quick-change wheels

The working platform is adjustable in height and fitted with folding railings. Pressure oil from a motor-driven pump serves to raise or lower the platform, while a screw spindle allows it to be tilted sideways so as to compensate for any super-elevation of the track. The vehicle is equipped with a second windscreen which is arranged so as to facilitate the examinations of overhead installations. Several vehicles of this design are in use on the electrified lines in Northern France, where the advantage is claimed that on repair work they block the track for a minimum of time.

An Atomic Energy Centre in Essen

A documentation centre for literature on atomic energy and radioactive isotopes has been opened in the House of Technology in Essen. About seventy scientists have volunteered to assist in collecting, sorting and evaluating specialised material for the centre. Pertinent foreign publications are to be translated into German, completely or in part. Later, courses are to be held for training employees of industry in nuclear physics. Such courses are to include an introduction to the construction and operation of the approximately twenty kinds of atomic reactors now in existence; instruction on the production of isotopes; ways of destroying or using radioactive fission products; and information on German liability laws in the sphere of atomic energy.

In his speech at the inauguration of the Essen centre, Under Secretary Professor Brandt of Dusseldorf suggested that chairs for nuclear research be established at German universities, for which, he said, a federal subsidy of about 60 to 80 million DM would be needed. Professor Brandt pointed out that the future role of German industry on the world market would largely depend on the progress of nuclear research in the Federal Republic.

ROYAL AGRICULTURAL SOCIETY.—The council of the Royal Agricultural Society has accepted an invitation to hold the Royal Show at Bristol in 1958, on a site at Whitchurch, about two miles south of the city. Next year, the Royal Show is to be held from July 3rd to 6th at Newcastle upon Tyne, and in 1957 at Norwich.

* "A Brief Review of Science and Technology in Western Germany." London: H.M. Stationery Office for D.S.I.R. Price 4s. (72 cents U.S.A.).

Industrial and Labour Notes

The Factory Inspector's Report

The annual report of H.M. Chief Inspector of Factories (Sir George Barnett), for the year 1954, was published a few days ago (H.M. Stationery Office, price 8s.). It says that last year the factory "population" was the highest recorded in peacetime, though the total number of power factories registered, 212,909, was about 2000 less than in 1953. Similarly, there was a decrease in the number of non-power factories from 21,032 to 18,955. It is added that the number of building operations notified increased by 10 per cent during last year and that the number of works of engineering construction also increased.

In his introduction to the report, Sir George Barnett says there is no doubt that automation has a considerable future in this country for mass production work, though he does not visualise "any drastic overnight changes." The factory department of the Ministry of Labour, the report continues, is watching the development of automation with considerable interest, in the expectation that eventually it will influence the cleanliness of the factory and increase its safety, because the machine will be remote from its human supervisor. Automatic handling, too, is bound to increase, which will, in its turn, eliminate many accidents due to handling goods and materials. There is also, Sir George observes, a strong possibility of an increase in shift working because clearly automation would otherwise be uneconomical.

Factory Lighting and Colour

According to the Factory Inspector's report, there was "substantial progress" throughout last year in the provision of natural and artificial lighting in factories. The report says that architects and occupiers are fully aware of the advantages of good natural lighting, not only in obtaining efficient performance of the visual task, but also in providing a cheerful and "open-air" atmosphere.

In existing factories, however, especially in older ones, an increase in natural lighting can only be obtained at some expense, so that progress tends to be slow. But, the report comments, a little ingenuity can help, and better natural lighting has been obtained at comparatively small cost by the replacement of wall sheeting of corrugated asbestos or iron by corrugated transparent plastic, by the substitution of old cast iron window frames by modern ones, or by the use of prismatic glass to throw more light into the room. Furthermore, the report notes, it is all too frequently forgotten that natural lighting cannot be maintained without window-cleaning!

The report also records that "the value of colour in factories has now been firmly established." Its use, originally confined to the cleaner industries, is extending to the industries at one time described as dirty and drab.

Factory Accidents

The Factory Inspector's report, referred to in the preceding note, says that in 1954, for the second time since the war years, there was an appreciable increase in the number of accidents. In factories only, the number of accidents increased from 158,597 in 1953 to 161,458 last year, or by 1·8 per cent. The accidents occurring at other places coming within the purview of the Factories Acts increased from 23,040 to 23,709. The number of fatal accidents last year in all premises subject to the provisions of the Factories Acts was 538. In factories only, the accident rate per thousand workers was 22·4 last year, compared with 22·7 in 1953 and 22·5 in 1952. In 1937 the accident rate per thousand workers was 30.

The report says that the small variation in rate during the last three years is due to a number of factors, the significance and effects of which are difficult to assess and analyse. Since 1952 industrial production has been steadily rising. This, the report comments, has not merely involved an increase in the number of persons employed, but has involved more overtime working, less short-time working, an increase in the tonnage of materials handled, and, perhaps most important of all, the absorption into the ranks of the employed population of many people who are taking employment in factories for the first time and are unfamiliar with industrial hazards.

The section of the report dealing with accidents analyses in some detail accidents to young persons and to older workers, and devotes one chapter to accident prevention organisation. The Chief Inspector urges that a real attempt should be made to bring the accident rate for women below the level of 10 per 1000, about which it has fluctuated since 1951. The report also emphasises, once again, that accident prevention organisation within the factory is the road to progress in reducing accidents. It is acknowledged that the importance of the human factor in accident prevention is now more widely realised than formerly, but, the report says, to ensure the continuous co-operation of workers which is so essential there must be some individual in each organisation with qualities of leadership, initiative and enthusiasm sufficient to overcome apathy, whether of management or workers.

Coal

In the first forty-nine weeks of this year, ended last Saturday, coal production totalled 209,774,500 tons, which included 198,805,400 tons from the deep mines and 10,969,100 tons from opencast sites. In the comparable period of last year, the total output amounted to 212,260,300 tons. Last week's output, which totalled 4,826,600 tons (including 4,584,400 tons from the deep mines) was the highest for a year. In the first forty-eight weeks of this year, coal imports amounted to 10,792,900 tons. Distributed coal stocks on December 3rd were 19,657,000 tons, compared with 17,130,000 tons on the corresponding date last year.

At the end of last week it was stated that the executive of the National Union of Mineworkers had submitted a wage claim to the National Coal Board. The claim is on behalf of the various grades of day-wage men, and thus comprises the majority of the industry's labour force, apart from piece workers at the face. It is understood that the union is asking for the rates to be raised by 3s. 4d. a shift. The president of the union, Mr. Ernest Jones, has been reported as saying that the hope was that the wage increase would check the drifting away of the day-wage men to other industries.

Employment and Unemployment

In its latest report on the employment situation in Great Britain, the Ministry of Labour says that, at the end of October, the total working population was 24,061,000, or 43,000 more than a month earlier. The number of people in civil employment in October was 23,059,000 (15,224,000 men and 7,835,000 women), which was 29,000 more than at the end of September.

An analysis of the civil employment figures indicates that, in October, the number of people employed in the basic industries declined by 36,000 to 3,973,000. The greater part of the decrease may be described as seasonal, as it occurred in agriculture, but there was a further drop in coal mining manpower, the number of workers on colliery books at the end of October being 699,000, compared with 704,000 a year earlier. In the manufacturing industries the manpower total increased by 52,000 in October to 9,374,000. The biggest increase, 16,000, was in the engineering, metal goods and precision instruments group, where 2,819,000 were at work. in October, compared with 2,693,000 a year earlier. The number of people employed in vehicle building increased by 6000 to 1,256,000.

About unemployment, the Ministry of Labour states that on November 14th there were 225,913 people registered as out of work, compared with 215,155 on October 10th. The November figure, which represented 1 per cent of the total number of employees, included 10,705 who were temporarily stopped and 78,105 who had been unemployed for more than eight weeks.

Retired Senior Officers for Industry

The Federation of British Industries has lately been giving careful attention to the problem of absorbing into useful employment retired senior officers from the three armed services and the overseas civil service. There can be no doubt, the F.B.I. says, that very many of these men deserve better when they compulsorily retire in the early or middle fifties than the disheartening hunt for satisfactory employment or the rustication which is the fate of so many of them. The numbers involved are not large; there is no problem with technical officers, but only with those whose careers have been devoted to general administrative duties.

As a result of the Federation's examination of the problem, it has been decided to institute at the Polytechnic, Regent Street, London, a series of five-week "industrial appreciation" courses for senior officers. Retired officers of the rank of Colonel, or its equivalent, and above, wishing to take the course are first interviewed by a selection panel set up by the Federation. The Federation has also set up an advisory council consisting of industrialists and representatives of other interested bodies to supervise the scheme in general and to advise the Polytechnic on the syllabus for the course. The chairman of this council is Mr. W. H. McFadzean, of British Insulated Callender's Cables, Ltd.

A leaflet setting out the details and procedure of the scheme has been prepared. It may be obtained (price 3d.) from the Federation of British Industries, 21, Tothill Street, London, S.W.1.

Industrial Advisory Service for Manufacturers

The National Union of Manufacturers has circulated some particulars about the progress of the industrial advisory service, which it set up about two years ago, with the assistance of an initial grant under the Conditional Aid Scheme. The intention was to provide a source of experienced and independent advice, mainly for the benefit of medium-sized and smaller firms, on those business problems falling within the sphere of management and production organisation. Mr. G. L. Page, A.M.I.Mech.E., was appointed industrial adviser.

It is stated that the experience of the last two years has clearly shown the value of the service. The service has now, therefore, been put on a permanent basis by the National Union of Manufacturers, and arrangements have been made to expand it so that firms can obtain practical assistance in carrying out the industrial adviser's recommendations. For this purpose a small team of industrial assistants has been appointed to the advisory staff to carry out agreed programmes. They will operate under the direct supervision of the industrial adviser and appropriate charges are to be made for their services. The scope of the service, therefore, is twofold; it includes the giving of advice and, where necessary, practical assistance in implementing it.

The National Union of Manufacturers says that its industrial adviser is available to visit any firm which has a particular problem concerning management and production organisation, or desires an independent appraisal of the scope for improving productivity. If desired, the firm may be given a report summarising the main directions for improvement, and indicating ways in which it can be achieved. The industrial assistants are available, on short term assignments, to help smaller firms in particular to reduce costs and to raise productivity, mainly through the application of work study. Full details and conditions of the service are available from the Industrial Adviser, National Union of Manufacturers, 6, Holborn Viaduct, London, E.C.1.

National Metal Congress and Exposition

No. I

BY OUR AMERICAN EDITOR

THE 37th National Metal Congress and Exposition was held in Philadelphia, Pennsylvania, from October 17th to 21st. As in previous years, it was sponsored by the American Society for Metals, the American Welding Society, the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers, and the Society for Non-Destructive Testing. Some 450 companies engaged in either the production, treatment or fabrication of metals gave displays and demonstrations of their products or services at the exhibition, which was held at the Philadelphia Convention Halls. Over the years, the Metal Show has continued to become ever broader in its coverage of the metals and metal working field, and gone are the days when it was concerned mainly with the heat-treatment of steels. This year there was again a strong accent on the fabrication and application of some of the more recently developed metals such as titanium, zirconium, magnesium and tantalum, and nuclear fuel elements were displayed for the first time at this exhibition. Furthermore, there was a noticeable trend toward the display of vacuum melting furnaces and of vacuum-cast metals, and one also noticed the growing application of ultrasonic equipment in the fields of cleaning, cutting and non-destructive testing.

The Brush Laboratories Division of the Clevite Corporation, Cleveland, Ohio, recently entered the field of titanium fabrication and exhibited a number of components made of "Ti-Brush 40." This material is a high-purity unalloyed titanium, and its excellent ductility enables it to be formed to sheet, rods, tubes, and complicated extruded shapes at moderate temperatures without contamination. Its high ratio of fatigue strength to tensile strength and its good toughness qualify it for applications where dynamic loading is present. It has the following chemical and physical properties :

Chemical Analysis :

Carbon	Typical 0·05 per cent. Maximum 0·10 per cent.
Nitrogen	Typical 0·015 per cent. Maximum 0·04 per cent.
Iron	Typical 0·01 per cent. Maximum 0·20 per cent.
Oxygen	Typical 0·12 per cent. Maximum 0·20 per cent.
Hydrogen	Typical 0·0030 per cent. Maximum 0·0050 per cent.
Magnesium	Typical 0·05 per cent. Maximum 0·10 per cent.

Density :

0·163 lb per cubic inch.

Tensile Properties :

Yield strength (0·2 per cent offset)	40,000 lb per square inch minimum
Tensile strength	60,000 lb per square inch minimum
Elongation in 1in ...	30 per cent minimum
Reduction in area ...	50 per cent minimum.

In fabricating the components exhibited from titanium sponge, the firm used two powder metallurgical methods : hot pressing and press forming. In the hot pressing method, high vacuums and temperatures are used to prevent gaseous contamination and to remove volatile constituents such as magnesium and magnesium-chloride. Graphite dies have been found satisfactory for producing high density, ductile parts having dimensional tolerances of approximately $\frac{1}{16}$in depending entirely upon the shape of the part. Parts weighing as much as 125 lb and as large as 9in diameter have been produced with present equipment. Fabrication by this method lends itself readily to the prototype production of contoured cored shapes which are normally produced by casting methods. The utilisation factor on intricate parts is generally less than 4·5 lb of sponge to make a 1 lb finished machined part. Surface contamination by the graphite is kept at a minimum ; and for most parts, the contamination is less than 0·005in deep.

The press forming method is ideally suited for the production of parts in large quantity at low cost. Blanks or semi-finished shapes are pressed from powder and sintered in vacuum ; as in hot pressing, this processing tends to remove volatile constituents. The pieces are then given a series of forming operations to produce a part of finished shape. Operations such as forming, extruding, rolling and drawing may be performed after the initial sintering. The utilisation factor is low, 1·7 lb of sponge generally being required to make 1 lb of titanium. High density or controlled porosity may be obtained by this process. To attain a part of maximum density, a subsequent series of forming operations are necessary depending upon the design of the end product. Sintering or annealing operations are desirable between each pressing operation, the final operation being a stress relief anneal prior to finish machining.

At this year's Metal Show nuclear fuel elements and their components were exhibited for the first time by the Metals and Controls Corporation, Attleboro, Massachusetts. This firm has been engaged since 1952 in the fabrication of fuel elements and fuel element components for the U.S. Atomic Energy Commission and its contractors. A complete plant for the production of fuel elements is now in operation and is available to serve authorised concerns for industrial needs, whether for small thin gauge foils for experimental application or for complete fuel assemblies. Since 1916, the Metals and Controls Corporation has specialised in the production of bonded metals and has pioneered in the commercial production of new and unusual metals either as bonded composites or as fabricated pure metals. This experience has been applied to fuel element manufacture, and is now available to others in the expanding American nuclear energy programme.

Uranium, either enriched or natural, or thorium, can be rolled in kilogramme lots to gauges as thin as 0·0006in ± 0·0002in. These foils can be used in research experiments, such as cross-section determinations, or can be supplied clad with metals or plastics for zero power research reactors or critical experiments. Consumable and tungsten electrode arc melting facilities as well as vacuum induction melting furnaces have been developed for the preparation of alloys of uranium and thorium with zirconium, aluminium or other metals as required. These alloys can be supplied either bare or clad with other metals or plastics for the complete fuel element or assembly. Fuel elements can be made by extrusion processes, using either integral end enclosures or co-extrusion, butt-welded end caps being subsequently attached. Extrusion of oxide and metal powder combinations for fuel elements also has been accomplished. Flat plate elements, either with alloy cores or oxide-in-metal cores, have been made. Fuel elements or fabricated shapes have been supplied by the firm for the Thermal Test Reactor and Submarine Intermediate Reactor at the Knolls Atomic Power Laboratory, and for critical experiments at the Oak Ridge National Laboratory, as well as for classified reactors at the Savannah River Plant, the Hanford Plant and the Argonne National Laboratory of the U.S. Atomic Energy Commission.

A new tool material, which is likely to become of great importance to production engineers, was exhibited at the stand of the Carboloy Department of the General Electric Company, Detroit, Michigan. The material is known as cemented oxide and will become available commercially early in 1956. Initial tests of cemented oxide indicate that the material may be used successfully for finishing operations at top speed ranges of standard machine tools. Its performance, however, is considerably improved at speeds in excess of 1000 surface feet per minute. Although no coolant is required the material may be used with coolants if heat deformation of the work is a factor to be considered. The tool material does not heat up, and is generally cool to the touch following a machining operation. Most of the heat is transferred to the chip and some to the workpiece. Tips of the new material have been used to machine materials such as S.A.E. 4340 and nickel-chromium-molybdenum steels with Brinell hardnesses up to 300. The wear resistance of the material indicates a tool life more than twenty-five times greater than that of cemented carbides. It has been found that tool tips of cemented oxide can be wet ground successfully with 220-grit diamond wheels. The use of finer diamond wheels is possible, but a longer grinding time is required. Silicon carbide wheels have been used for rough grinding only. A honed edge around the cutting edge and the nose radius of the tool tip is essential to obtain satisfactory results. At present, tool geometries of 5 deg. to 10 deg. negative back and side rake, relief angles of about 10 deg., side cutting edge angles up to 60 deg. and nose radii of $\frac{1}{16}$in seem to be most successful.

The cemented oxide material was developed specifically as a cutting tool material and for wear applications. It was not developed for insulation or general usage as were many of the ceramics which have been tested as cutting tool materials. Several attempts have been made in the past by Carboloy to develop ceramic materials specifically for cutting tools. The present material, which has been under development since 1951, was the first composition to emerge from this programme with properties to warrant appraisal. It is stronger and appears to resist chipping better than other ceramics. Cemented oxide has a transverse rupture strength of 80,000 lb to 100,000 lb per square inch, a density of 4·10 to 4·20, and a hardness of 93 to 94 on the Rockwell A scale. It offers very good resistance to oxidation, and is generally resistant to corrosion. In addition to use as cutting tool materials, the above properties suggest applications where high temperature strength together with low density, resistance to oxidation at elevated temperatures, and combined abrasion and corrosion resistance are required. Cemented oxide is made of materials which are in abundant supply and is processed by powder metallurgy techniques.

In one performance test, cemented oxide was used in a turning operation to clean off the outside diameter of the wheel on the shaft end of a gas turbine. The material was S.A.E. 4340 steel hardened to 260 Brinell and the carbide used in the operation is normally run at a speed of 250 surface feet per minute. For the cemented oxide material, the machine speed was increased to 300 surface feet per minute. Using the same depth of cut and feed used with the tungsten carbide (0·060in and 0·010in) the cemented oxide material showed hardly any wear after making the $\frac{1}{16}$in cut on the 16in diameter wheel. Similar results were obtained when the depth of the cut was made $\frac{1}{8}$in at 485 surface feet per minute with the feed at 0·010in. The tool life of the carbide would have been shortened considerably at the accelerated machine speed. The cemented oxide tool was also tried in making a 6$\frac{1}{2}$in facing cut on the hub of a 7ft diameter sixth-stage steam turbine bucket wheel being machined on a Cincinnati 100in "Hypro" boring mill. The inside diameter of the hub was 26$\frac{3}{4}$in with the outside diameter measuring 39$\frac{3}{4}$in. The material was a chromium-molybdenum steel with a Brinell hardness between 220 and 240. Normally, the operation was run at 180 surface feet per minute with carbide, but for this test the machine speed was increased to 425 surface feet per minute. Before making the hub cut, the cemented oxide tool was used to make a complete 3$\frac{1}{4}$in facing cut on the rim of the wheel at 1100 surface feet per minute, and a complete one on the hub at 425 surface feet per minute. Then, to obtain a comparison, the same cemented oxide tool was used to make another half of a cut on the hub, finishing off the remaining half with a new carbide tool normally applied on the job. In Fig. 1, we show the wear on the cemented oxide tool after making the 2$\frac{1}{2}$ cuts, compared to wear obtained on the carbide tool

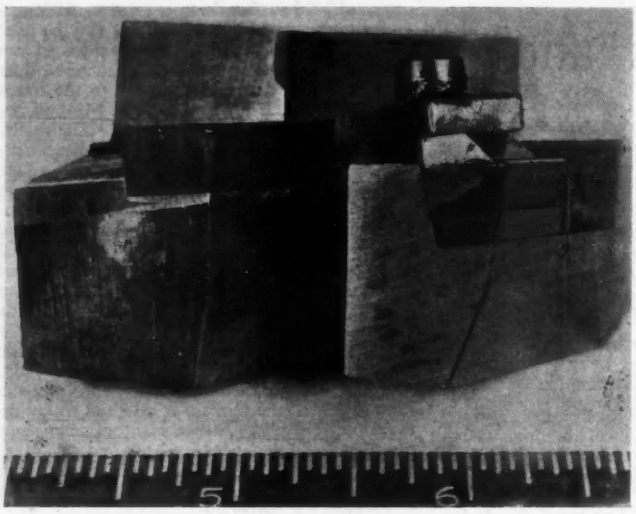


Fig. 1—Comparison of wear on cemented carbide tool (left) and cemented oxide tool (right)

making only half a cut on the hub. The wear land on both tools was about 0·010in.

The new material has also been used on softer steels, and on S.A.E. 1045 steel finishing cuts were taken at 1800 to 2000 surface feet per minute. A tool life of about 25 minutes was obtained at 2000 surface feet per minute with depths of cuts of 0·010in and feeds of 0·005in.

The Beryllium Corporation, Reading, Pennsylvania, exhibited several interesting cast beryllium copper forging dies which were recently developed for light alloy forging purposes in co-operation with an American manufacturer of airframes. While the well-known Kirksite " A " zinc-base alloy had been used for some time by the aircraft industry for short runs of aluminium forgings, there had been a great need for a die material that would overcome the limitations of Kirksite for short runs of steel forgings, long runs of aluminium or magnesium forgings, and forgings of large parts in hydraulic presses having a dwell time cycle of 15 seconds or more. In a search for a better forging die material, many alloys had been investigated, and so far, beryllium copper seems to offer the greatest advantages in strength and casting characteristics. Although beryllium copper is more expensive initially, the material cost is not a major factor, since the dies can be re-melted and re-used by adding virgin alloy. The majority of the dies produced by the firm up to the present have been in " Berylco " 20 C alloy, overaged to a Rockwell hardness of approximately C 35. The overaging heat treatment was employed to increase the impact resistance, and at the same time to provide a safety margin until sufficient experience had been gained with the experimental dies.

Initially, in order to prove the feasibility of beryllium copper forging dies, the company forged several aluminium doll heads utilising a sand cast beryllium copper mould ordinarily used for the injection moulding of plastics. With this very crude arrangement the results were sufficiently encouraging so that subsequently an experimental order was placed for the production of 100 14-S aluminium forgings from a cast beryllium copper die. This particular part was very small but was successfully produced without the aid of any steel backing on the beryllium copper dies. After this initial die proved satisfactory, the forging company participating in the development work received an order to produce a number of 14-S aluminium alloy forgings using a beryllium copper die. This particular forging was chosen because it was an extremely difficult job, and it was felt that a true test of a beryllium copper die would be obtained. The forgings were made on a 2000 lb drop hammer. After forging several parts, it was noticed that there evidently had been some slight subsurface porosity present in the casting, which caused small pimples to appear on the forging. This condition gradually became worse and, after the fourteenth part, forging was terminated. Since that time, the Beryllium Corporation has developed foundry techniques which eliminate the sub-surface porosity found on this first set of dies.

Subsequently, another forging company machined a set of beryllium copper dies from wrought material in an effort to compare their life with that of steel dies. The dies were hardened to Rockwell C 30 by overaging and were used to forge S.A.E. 1090 steel at 2250 deg. Fah. on a 600 lb drop hammer in one blow. After 400 pieces, the ends of the dies spread approximately 0·007in. Another set of dies was tried which had been aged to a Rockwell hardness of C 40. On this particular set, 1000 pieces were obtained before the dies went out of tolerance. It should be noted, however, that each die had a very irregular contour on its face, with ends extending above the die holder, which probably contributed to the spreading. At present, the Beryllium Corporation is willing to accept orders for dies weighing up to 5000 lb. The largest die which has actually been produced so far weighed approximately 1200 lb.

Consumable Electrode Melting Under Vacuum

On the opening day of the Metal Show, the Allegheny Ludlum Steel Corporation, Pittsburgh, Pennsylvania, announced the availability of nickel, cobalt and iron-base " super-alloys " and other specialty steels made by a newly installed vacuum remelting facility using the consumable electrode process. In Fig. 2 we show two consumable electrode vacuum melting furnaces installed at the Watervliet, New York, works of the company.

Consumable electrode melting of metals under vacuum is not new, and this method has been used commercially in melting materials such as titanium, zirconium and molybdenum. Some modifications in the process were made in applying the melting principle to super-alloys. The procedure consists of making cast electrodes of an alloyed, predetermined composition from a large production size electric furnace air melt and then remelting these electrodes under vacuum by arc melting in a water-cooled copper crucible. To date, vacuum melted ingots up to 12in diameter by 1000 lb weight have been made from nickel-base super-alloys, and up to 16in diameter by 2000 lb weight in the iron-base super-alloys, as well as in stainless and other steels. Test results on finished products made from these ingots suggest that the process offers the following advantages over direct-arc furnace melted materials :—(1) A higher degree of cleanliness attained through the removal of non-metallic inclusions and excess gases ; (2) a better compositional homogeneity through freedom from segregation ; (3) an improved workability and ingot soundness resulting in increased yields, and (4) a general improvement in mechanical properties. Over 300,000 lb of various alloys have been melted in this manner by the company, and as a result, some of the materials have now passed from the development into the production stage.

Some of the advantages of consumable electrode vacuum remelted materials over air melted materials are summarised here.

Lower Gas Content.—On vacuum remelting by the consumable electrode process, it was found that a considerable amount of degasification occurs. During the arc melting action there occurs in the molten pool of metal the formation and growth of a bubble containing gases which are expanded under the high temperatures involved. When the gas pressure becomes sufficiently high, the bubble bursts, and the gases are withdrawn by the vacuum. Similarly, gases are withdrawn from smaller metal droplets on transfer from the electrode to the molten pool without bubble formation where the high ratio of surface area to volume permits an easy withdrawal of the gases. Chemical analyses for hydrogen, oxygen and nitrogen have been made on the air-melted electrodes and their corresponding vacuum remelted ingots of various super-alloys. The gas removal that occurs on vacuum remelting, and the final gas contents, are of the same magnitude as obtained in induction vacuum melting.

Improved Cleanliness.—The consumable electrode vacuum remelting results in a considerable improvement in the cleanliness of the original air-melted material. Nickel-base and iron-base super-alloys containing titanium are very difficult to melt cleanly in an air atmosphere. The main problem is the formation of titanium oxides, nitrides, or carbon-nitrides, which are found in finished rolled bars or billets as non-metallic stringers. Increased cleanliness and freedom from such stringers is obtained in the same size of bar made from a consumable electrode remelted ingot. This significant improvement in cleanliness has been obtained in the nickel-base, titanium-hardened alloys such as " M–252 " and " Waspaloy," and in the titanium-containing stainless grade A.I.S.I. 321. There is also a general improvement in the cleanliness of low-alloy, high-speed and other stainless steels made by this method. The freedom from stringers and other inclusions results in a significant improvement in the workability of these materials during certain hot working or cold forming operations. Extremely severe hot upsetting of pickled bars was performed as a laboratory control test. The air-melted material containing such stringers cracks on the outer surfaces on drastic upsetting, while the consumable electrode-melted material does not rupture. Such tearing of air-melted material, due to stringers, either limits the amount of hot or cold reduction to which the material can be subjected, requires frequent grinding operations during intermediate stages of a forging cycle, or necessitates rough turning of the bars or billets prior to such operations.

It is believed that the cleaning up of the air-melted material during arc remelting under vacuum occurs in two ways : (1) dissociation of less stable oxides or compounds under the low pressures and high temperatures involved. It is estimated that the arc temperatures are in excess of 6000 deg. Fah. or greater than twice the temperatures normally used in induction vacuum melting ; (2) levitation or floating out of the more stable compounds, such as titanium nitrides, which have a lower specific gravity than the parent metal.

Improved Tensile Properties.—In a number of applications, such as gas turbine wheels, high-tensile ductilities are required in the centre of the part. This ductility is related to the cleanliness and segregation in the centre of the large billet sections from which these parts are made. The tendency toward heavy centre segregation particularly applies to materials containing high-density elements, such as molybdenum and tungsten, in super-alloys as well as in high-speed steels. In turbine wheel materials, such as the A–286 alloy, it has been found that the centre ductility decreases with increasing amounts of segregation which, in general, becomes progressively worse as ingot size increases. This segregation in conventionally solidified ingots is more severe in the top third portion of the ingot. As a result, the top portion of a finished billet is often unsatisfactory for these critical applications. However, this segregation problem is minimised, if not entirely eliminated, by consumable electrode vacuum melting because of the fast cooling and close control of solidification rates that cold mould-arc melting makes possible. Hence, increased productivity and savings of strategic alloys can be effected.

A comparison of room temperature tensile ductility in the A–286 alloy produced by conventional and consumable electrode vacuum melting was made. Transverse room temperature tensile tests were taken through the dead centre of the etch discs from top billets. Direct-arc, furnace-melted billets in the size range of 7in to

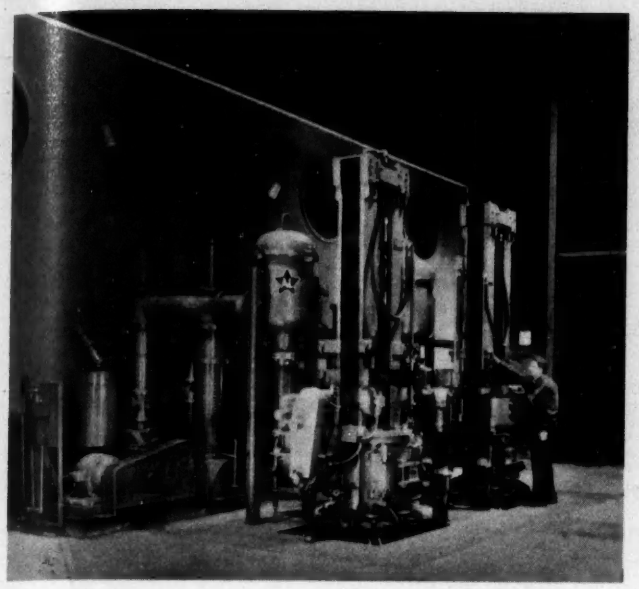


Fig. 2—Two consumable-electrode vacuum melting furnaces at the Watervliet works of the Allegheny Ludlum Steel Corporation

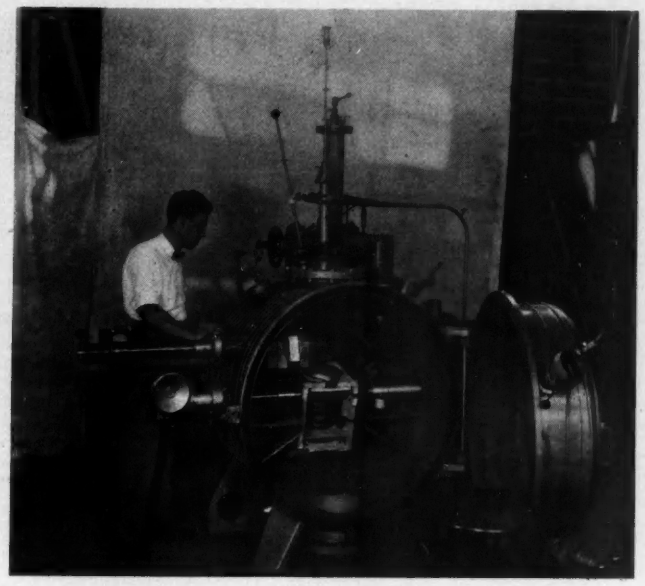


Fig. 3—50lb vacuum induction melting furnace made by National Research Corporation

9in and consumable electrode vacuum-melted billets in the size range of 7½in to 10½in square were tested, and an improvement in elongation and reduction in area was evident.

Improvement in high-temperature mechanical properties.—Consumable electrode vacuum remelting results in an improvement in the hot tensile ductility and stress rupture ductility of the "M-252" alloy. In addition, a 15 per cent improvement in the 1500 deg. Fah. fatigue strength has also been reported. The levels of these properties compare favourably with those obtained in induction vacuum melted material.

With regard to costs, it is difficult to predict whether induction vacuum or consumable electrode vacuum melting will be more economical as the size of furnaces and ingots increases. Capital investment, maintenance, upkeep and labour costs will be great factors and will undoubtedly vary from shop to shop. The extent to which each of these melting procedures can be mechanised will have a significant effect on costs. One disadvantage of consumable electrode vacuum melting is that the pool stays molten for a relatively short length of time, thereby limiting the extent of degasification. Factors which tend to counterbalance this are the higher temperatures involved and the fact that the melting in a cold metal eliminates the possibility of contamination by refractory materials to which an induction vacuum melt is exposed. In addition, the progressive melting and vertical solidification affords the opportunity to levitate exogenous inclusions due to their lower specific gravity. One means of producing high purity alloys in large ingot sizes and quantities would be by combining the two processes, i.e. by casting electrodes from an induction vacuum melt and subsequently remelting under vacuum by the consumable electrode process. The firm's research programme will explore this technique by producing cast electrodes weighing 1000 lb from an induction vacuum melting furnace.

Vacuum Melting

The general progress of vacuum melting in the United States was reflected by various exhibits at the Metal Show. The Vanadium-Alloys Steel Company, Latrobe, Pennsylvania, displayed various vacuum-melted alloy steel components and stated that its sales of vacuum-melted metals have shown a constant increase, making necessary the installation of additional equipment. This firm's association with the Carboloy Department of the General Electric Company, a manufacturer of vacuum-melted steels, is typical of the growing interest which American steelmakers are taking in the vacuum melting process. To-day 1000 lb capacity vacuum furnaces are in operation at the Utica Drop Forge and Tool Corporation, the Carboloy Department and the Universal-Cyclops Steel Corporation. While in 1954 American vacuum metals production was estimated at 25 tons a month, the additional installations coming into operation this year have increased production to about 100 tons per month.

The 50 lb vacuum induction melting furnace, model 2555 (Fig. 3) which was exhibited at the stand of the National Research Corporation, Newton Highlands, Massachusetts, is representative of current American practice employed in the development and semi-production of new alloys having improved metallurgical properties made possible only by melting and casting in a vacuum or an inert atmosphere. The furnace is equipped with a ganged four-container late-addition assembly which permits charging special alloy ingredients in any order and at any rate desired. Unlimited bulk additions, without breaking vacuum, can be made with a charging assembly and air lock. This assembly ensures that the charge material is all delivered to the crucible with a minimum drop and at the desired rate, with no danger of stray material jamming the mechanisms. A rotary mould table allows pouring into several small moulds, without breaking vacuum, for investment casting or for "split-heat" research. This table is removable to permit the use of a single large mould. Among the optional accessories available are smaller interchangeable assemblies, mould heaters, a power feed-through, a thermocouple feed-through, a mould port, moulds, and an immersion thermocouple assembly with air lock and recorder.

The furnace chamber comprises a 42in diameter stainless-steel horizontal furnace tank with a dished head flanged for a hinged door and clamps. Copper cooling coils are brazed to the tank and door, all gasketed joints being cooled. The maximum system leak-rate is 15 microns rise per hour at a pressure of 1 micron with the tank clean, dry, empty and outgassed, and excluding crucible and crucible insulation. The crucible capacity is 50 lb (rated in steel) but interchangeable 30 lb and 17 lb crucible and coil assemblies are also available. The pumping system of the furnace comprises one NRC 100-S, 100 c.f.m. mechanical pump driven by a 5 h.p. motor, one NRC 2-S, 1·25 c.f.m. mechanical holding pump driven by a ¼ h.p. motor and one NRC B-6 high vacuum booster pump with 9kW heaters designed to obtain an ultimate vacuum of 0·3 micron. The power supply for the installation is provided by a 50 h.p. 220V, or 440V, three-phase 60 c/s motor-generator set having an output of 30kW at 4200 c/s, 220V single-phase. The vacuum instrumentation comprises a direct-reading NRC Model 517 "Alphatron" ionisation vacuum gauge with six scales covering a range from 0·1 micron to 1000mm for measuring chamber pressure. There is also a NRC Model 701 thermocouple gauge control to measure the forepressure of the mechanical and booster pumps.

It is of interest to note that the National Research Corporation has now reached an agreement with Leybold Hochvakuum Anlagen G.m.b.H. of Western Germany, giving it exclusive rights for licensing the Bochumer Verein vacuum chamber steel degassing process to American steel works. This German process makes it possible to handle 150-ton ingots and was described in our issue of April 29, 1955.

(*To be continued*)

Commercial Production of Uranium Feed Materials

The U.S. Atomic Energy Commission has announced that it is inviting proposals for the production of refined uranium salts in privately owned and operated facilities. This action represents another step in the Commission's efforts to expand the scope of private participation in the uranium industry. The processes employed in the atomic energy programme to convert the uranium content of ores to the desired form consist of mining and milling of ores to produce a concentrate, refining the concentrate to produce a purified salt, conversion of the salt to metal or UF_6 and, in the case of metal, fabrication into suitable shapes. At the present time the extent of participation by private industry in these activities is limited to the mining and milling steps.

Specifically, the Commission is interested in receiving proposals from qualified firms to process, over a five-year period, uranium ores or concentrates to either uranium tetrafluoride, or uranium hexafluoride, with deliveries to begin about July, 1958. The Commission will consider proposals for any production rate up to a maximum of 5000 tons U_3O_8 equivalent per year. Proposals may be based on arrangements whereby the U_3O_8 concentrates are supplied by the Commission and refined salts returned or, alternatively, the Commission will consider proposals for direct purchase of the refined salts from a company having or obtaining its own supply of uranium ores or concentrates. In the latter connection the Commission will consider appropriate modifications in contracts now in effect between the A.E.C. and suppliers of uranium concentrates. Appropriate cancellation provisions would be included in any contract, as well as options to extend with appropriate price adjustments to reflect the amortisation status of the facilities.

Personal and Business

Appointments

MR. M. J. VEREY has been appointed a director of Dewrance and Co., Ltd.

MR. W. R. BISHOP has joined the board of J. A. Prestwich Industries, Ltd.

BRIGADIER KENNETH HARGREAVES has been elected president of the Chartered Institute of Secretaries.

MR. B. W. OWEN has joined the board of Howard S. Cotton, Ltd., 88-92, Rochester Row, London, S.W.1.

MR. P. C. PRITCHARD has been appointed assistant sales manager of George Ellison, Ltd., Perry Barr, Birmingham, 22B.

PETTERS, Ltd., Staines, states that Mr. D. A. Law, chief designer, has been appointed chief engineer, in succession to Mr. C. H. Bradbury.

FOLLAND AIRCRAFT, Ltd., Hamble, Southampton, announces the appointment of Mr. Derek Brade as chief flight development engineer.

MR. G. W. ALEXANDER, Mr. W. Messer and Mr. G. W. Davidson have been appointed directors of Rhymney Engineering Company, Ltd.

MR. J. C. Y. BAKER has been elected chairman, and Mr. J. E. Gray and Mr. R. Whitehead, vice-chairmen, of the Junior Institution of Engineers.

MR. W. R. TOMKINSON has been appointed chairman of Tiltman Langley, Ltd., in place of Mr. A. Hessell Tiltman who has resigned from the board.

Mr. H. GORDON MCHAFFIE, A.M.I.E.E., has been appointed director and general manager of The British Thomson-Houston Company (Canada), Ltd., Toronto.

J. AND H. MCLAREN, Ltd., Leeds, states that Mr. J. Allan has been appointed London area sales manager, and Mr. D. Hughes, North Eastern area sales engineer.

CROMPTON PARKINSON, Ltd., states that Mr. W. F. Griffiths has been appointed general manager of Crompton Parkinson (South Africa) Pty., Ltd., Johannesburg.

SIR REX HODGES has been appointed to the board of Automatic Telephone and Electric Company, Ltd., in place of Air Vice-Marshal O. G. Lywood, who has resigned.

MR. A. G. PEACOCK, of Mervyn Instruments, Ltd., has been elected chairman of the electrical and electronics section of the Scientific Instrument Manufacturers' Association.

THE DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH states that Dr. R. S. Millard, A.M.I.C.E., has been appointed head of the newly formed Colonial section of the Road Research Laboratory.

W. T. HENLEY'S TELEGRAPH WORKS COMPANY, Ltd., states that Mr. A. S. Brewer has been appointed advertising manager in succession to Mr. J. Dunford Smith, who has retired on account of ill health.

MR. P. J. C. BOVILL, assistant managing director of Newton Chambers and Co., Ltd., has joined the board of the Wellman Smith Owen Engineering Corporation, Ltd., Parnell House, Wilton Road, London, S.W.1.

MR. C. H. BRADBURY, M.I.Mech.E., has been apppointed chief technical executive of Simms Motor Units, Ltd., East Finchley, London, N.2. Mr. Bradbury has been chief engineer of Petters, Ltd., since 1949.

BRITISH INSULATED CALLENDER'S CABLES, Ltd., announces the appointment of Mr. G. W. Wheaton as manager of the Middlesbrough branch, in succession to Mr. R. N. Crawford, who is retiring at the end of this month.

THE UNITED STEEL COMPANIES, Ltd., announce the following appointments at the Appleby-Frodingham Steel Company, Scunthorpe: Mr. W. Geary, special duties concerned with management studies and statistics; Mr. T. P. Lloyd, works manager (services), and Mr. W. Jackson, works manager (steel).

Business Announcements

WEST INSTRUMENT, Ltd., 1, Newman Street, London, W.1, states that its telephone number is now Museum 6663.

THE HON. L. O. RUSSELL is resigning the directorship of the British Institute of Management, which he has held since the Institute's inception in 1947.

THE PLESSEY COMPANY, Ltd., Ilford, announces the formation of a subsidiary entitled Plessey Research, Ltd. Mr. A. G. Clark is the chairman and managing director.

THE BRISTOL AEROPLANE COMPANY, Ltd., has made an agreement with Fiat, concerning the installation of the Bristol "Orpheus" turbo jet in the Fiat G-91 light fighter.

DOWDING AND MILLS, Ltd., states that it has now started its own electrical contracting organisation at Bordesley, Birmingham, 12. Mr. J. Robinson is the manager of the organisation.

MR. W. V. ZINN, M.I.C.E., has moved his Westminster and Earls Court offices to new accommodation at Collingham House, Eagle Street, Southampton Row, W.C.1 (Telephone, Chancery 9451).

THE DORMAN SPRAYER COMPANY, Ltd., Ditton Walk, Cambridge, states that it has taken over the manufacturing and distribution of the hedge cutters and other equipment made by Baker and Hunt, Ltd.

THE FEDERATION OF ENGINEERING DESIGN CONSULTANTS has been established with offices at St. Stephen's House, Westminster, London, S.W.1. The chairman is Mr. Ray Body, of E. G. Irwin and Partners, Ltd.

TUFNOL, Ltd., Perry Barr, Birmingham, 22B, states that, on January 2nd, it will open a new branch office at Ellison House, Woodlands Terrace, Glasgow, C.3 (Telephone, Douglas 5335). Mr. J. D. Bruen is to be the branch manager.

BARR, THOMSON AND CO., Ltd., Kilmarnock, states that from December 23rd, its London office will be at 10, Norfolk Street, Strand, W.C.2. (Telephone, Covent Garden 0315; telegraphic address, "Tubenpipe, Phone, London").

AUTOMATION CONSULTANTS AND ASSOCIATES, Ltd., a new company with offices at 18, Berkeley Street, London, W.1, has been formed to provide advisory services in connection with all aspects of automation. The chairman of the company is Sir Walter Puckey and the members of the board are Mr. J. A. Sargrove, Mr. D. T. Myers, Mr. Andrew Tessler and Mr. H. E. Roff.

Contracts

THE ENGLISH ELECTRIC COMPANY, Ltd., has received a second order from the Nova Scotia Light and Power Company for a 45MW, 3600 r.p.m. steam turbo-alternator set, complete with feed heating and condensing plant, for installation at the Water Street Power Station in Halifax, Nova Scotia. The value of the order is approximately £450,000. The first set was ordered in July 1954, and this second set, like the first, will be built at the company's Rugby works.

Miscellanea

"ATOMS FOR PEACE" EXHIBITION.—The organising committee of the International "Atoms for Peace" Exhibition, held at Geneva in August, has recently met. In the light of the highly satisfactory results of this year's exhibition, the committee decided to organise another exhibition to be held in August 1957. The general secretariat of the committee has its headquarters at 1, Place du Lac, Geneva.

SCHOLARSHIP AWARDS.—The Council of the Institution of Naval Architects announces that it has awarded the Denny Scholarships in Naval Architecture to Mr. I. L. Buxton and Mr. A. D. J. MacGregor, and the Aluminium Development Association Post-Graduate Research Scholarship to Mr. G. Ward. Since Mr. Ward, owing to National Service, cannot take up the scholarship an interim award has been made to Mr. J. D. W. Green. The Duke of Northumberland's Prizes for 1955 were awarded to Messrs. J. G. Bell, R. C. Caws and M. J. Rushton.

ABRASIVE WHEELS.—A new design of abrasive wheel introduced by the Minnesota Mining and Manufacturing Co., Ltd., Birmingham, 8, comprises a "pack" of segments of coated abrasive cloth projecting from a central spindle mounting. When the wheel is rotated the abrasive sheets are able to flex so that the working face conforms to the contour of the work piece. This "self-profiling" action eliminates need for dressing a wheel face to the required contour prior to grinding or polishing an article. It is also stated that the efficiency of the wheel is maintained throughout its life as fresh grain is exposed as wear takes place.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.—On December 13th Dr. R. M. Kenedi, Mr. W. Shearer Smith and Mr. F. O. Fahmy presented a paper with the title "Light Structures—Research and its Application to Economic Design," to the Institution of Engineers and Shipbuilders in Scotland. The paper includes an analytical discussion of the experimental behaviour of thin-walled struts and beams and presents design charts intended for direct use in the drawing-office. There follows a description of a preliminary investigation into the behaviour of "in line" bolted joints formed in thin gauge material. Economic design and the derivation of optimum proportions, corresponding to maximum load carried per unit weight, for strut and beam elements are discussed in the light of "equal" and "part equal" strength sections. A description is given of full-scale tests carried out in the field on a three-hinged portal warehouse structure built entirely of cold rolled sections and a frameless oil tank roof, exemplifying the possibilities of thin-walled construction when applied with ingenuity and imagination.

INSTITUTE OF MARINE ENGINEERS.—"The Carriage of Edible Oil and Similar Bulk Cargoes" is the title of a paper read by J. Wormald, B.Sc. (Eng.), before the Institute of Marine Engineers on December 13th. The paper remarks that edible oil and similar bulk cargoes are usually carried in ships' deep tanks, which are constructed and fitted out for that purpose, and that successful carriage depends mainly on the preparation of tanks and, for solid fats, on temperature control during the voyage. A non-scientific background to official instructions, issued by shipowners and other authorities, is given to sea-going personnel concerned with the practical side of the carriage of these cargoes, and the paper presents in condensed form the experience gained over many years in the preparation and survey of deep tanks.

HEAVY-OIL ENGINE WORKING COSTS.—Yesterday, December 15th, the "Report on Heavy-Oil Engine Working Costs and Performance (1954)" was presented at a general meeting of the Diesel Engineers and Users Association. The report records that ninety-four stations made returns and that the lowest fuel consumption was 0·487 lb per kilowatt-hour from a generating station and 0·405 lb per water horsepower from a waterworks, while the lowest lubricating oil consumption was 8940 b.h.p. hours per gallon. The returns are printed in tabular form and Table I gives the cost per unit generated at forty home stations, which are divided into three sections, namely, installations containing mechanical injection engines only, installations containing air-blast and mechanical injection engines and installations containing only air-blast injection engines. Similar information but relating to thirty-six overseas stations appears in Table II, while Table III gives waterworks heavy-oil engine costs per water horsepower for eighteen home stations. Technical details of stationary mechanical injection and air injection engines appear in sections I and II, respectively, of Table IV and Table V contains the technical details of marine type engine performance. The results from generating stations and waterworks are summarised in Tables VI and VII.

IMPROVEMENTS ON THE LONDON–BIRMINGHAM ROUTE A.5.—Work has started on the £184,000 scheme to by-pass the village of Markyate, on the London-Birmingham-Holyhead Trunk Road, the A.5, in Hertfordshire. More than 10,000 vehicles a day use the southern half of this route, which forms the main route for the heavy industrial traffic between Birmingham and the South. Markyate is shown on seventeenth century maps as Market Street. The market has disappeared from the village but the street, which narrows to 16ft between kerbs at one point, has survived to impede traffic on the A.5. In 1935, a 15 m.p.h. speed limit was introduced and Markyate is one of the few places in the country where such a restriction exists. The new road will have an overall width of 60ft, with one 30ft carriageway and a footway. Considerable earthworks are involved; about 80,000 cubic yards of material will be excavated in cuttings and used to construct embankments. It is expected that it will take twelve months to complete the by-pass. The Markyate by-pass is one of a number of large schemes now progressing on the A.5, the total cost of which will exceed half a million pounds. They include major road improvement on a 5-mile stretch between Fosters Booth and Weedon in Northamptonshire and a by-pass at Loughton in Buckinghamshire. In addition, there will be a number of smaller widening schemes and, wherever possible, widening will be carried out when re-kerbing and resurfacing is being undertaken. It is the intention to provide at least two traffic lanes with a third overtaking lane throughout the greater part of the 259-mile length of the road. There will be dual carriageways on some sections. The work on the southern half of the road is being given high priority as an immediate measure to improve the flow of traffic between Birmingham and London.

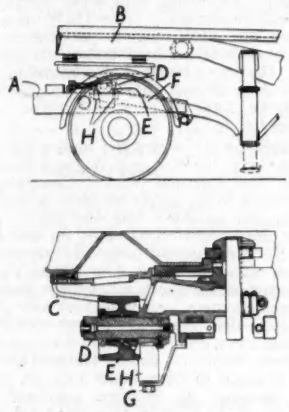
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgement is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgement, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.

ROAD TRANSPORT

738,697. March 20, 1952.—TRACTOR-TRAILER VEHICLES, Scammell Lorries, Ltd., Tolpits Lane, Watford West, Hertfordshire. (*Inventors: Laurence Derek Watts and Maurice George Hibberd Walter.*)

The invention relates to vehicles in which a tractor has ramps and load-carrying rollers on the trailer engage and ride over the ramps during the coupling and uncoupling operations of the trailer to the tractor. Referring to the drawing, the tractor and

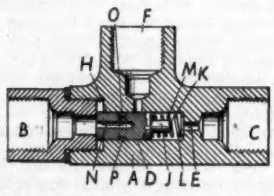


No. 738,697

trailer are indicated at *A* and *B*, and the turntable casting on the trailer at *C*. Mounted on shafts or pins *D* borne by the turntable are load-carrying rollers *E*. These rollers have a flat tread with no guide flanges. On the tractor are ramps *F* which may have replaceable wearing plates. The load-carrying rollers *E*, on coupling the tractor to the trailer, engage and ride over the ramps *F*. Mounted on members *G* of the turntable are four side-loading rollers *H*. These rollers abut against the sides of the ramps on coupling the tractor to the trailer and function as positive guides to prevent side-wise movement of the rollers on the ramps.—*October* 19, 1955.

738,188. February 12, 1953.—LUBRICATING APPARATUS, Clayton Dewandre Company, Ltd., Titanic Works, Lincoln. (*Inventors: Stanley Howard Edge and Dennis Albert Sams.*)

The invention relates to lubricating apparatus in which a lubricator is operated at intervals to discharge lubricant under pressure through to several points. In the design illustrated in the drawing the



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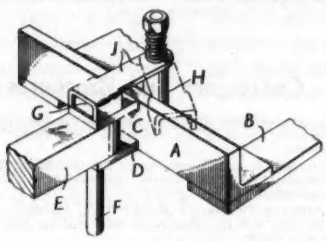
valve consists of a cylindrical housing *A* having an inlet *B* at one end and an outlet *C* at the other. Extending axially through the housing is a bore *D* whose ends open into the inlet and outlet respectively. The end of the bore which opens into the outlet a portion *E* of reduced diameter. Between its ends the housing has a branch outlet *F* which communicates with the bore. Slidably mounted within the bore is a piston-valve element *H* with a stem portion *J* of reduced diameter projecting from the end adjacent the reduced portion *E* of the bore. At the end of the stem a coned valve face *K* is formed for co-operation with an annular valve seat *L* surrounding the reduced portion of the bore. A spring *M* is interposed to bias the valve element away from its seated position. The body of the valve has an axial passage *N* which extends partially through from the end adjacent the inlet. The other end of this axial passage communicates through a transverse passage *O* with a circumferential groove *P* in the surface of the valve at a point intermediate the ends, such that when the valve is against the seat *L* the groove coincides with the passage leading to the branch outlet *F*. When the device is inoperative the valve element occupies the position shown in the drawing. Assuming that the connections on both the inlet and outlet sides of the valve are fully primed with lubricant, the operation of the device is as follows. When a full charge of lubricant is expelled through the outlet the pressure behind that charge is transmitted to the piston-valve element *H* through the lubricant which is present in the connection or delivery pipe leading to the valve inlet. The valve element is advanced by this pressure and expels lubricant from the space in the forward end of the bore through the reduced portion *E* into the valve outlet *C* and thence to the point requiring the reduced volume of lubricant. At the limit of its forward stroke the valve element seats and thus closes the outlet end of the bore. The actual volume of lubricant expelled by the valve element before it is seated can be predetermined, since it is governed by the volume through which the forward end of the valve element is displaced. It will readily be seen that an equal volume of the charge of lubricant originally expelled will have been taken up in displacing the valve element, so that a portion of the charge still remains under pressure. This portion is released through the branch outlet *F*, via the axial and transverse passages *N* and *O* in the bore and the groove *P*, as the valve element reaches the end of its advance stroke, at which point the groove comes into communication with the passage *G* leading to the branch outlet. The lubricant passing through the branch outlet can, by means of appropriate connections, either be delivered to another point requiring a reduced volume of lubricant or be returned to the inlet of the lubricator or the reservoir by which the lubricator is supplied. When this excess lubricant has been released through the branch outlet the valve element is free to be returned by the coil spring *M* to its initial retracted position.—*October* 12, 1955.

737,232. August 6, 1953.—TRAILER COUPLINGS, Walter Edward Purser, 10, Station Road, Castlethorpe, Wolverton, Buckinghamshire.

The invention relates to couplings for connecting trailer vehicles to automobiles, and is concerned with quick-release couplings. As the drawing shows, a tractor bar *A* of "L" section is attached to the towing vehicle by means of brackets *B*. Projecting



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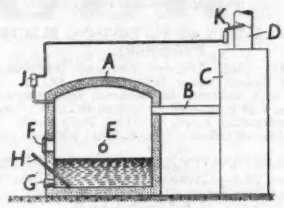
rearwardly from the centre of the vertical limb of the bar are two lugs *C* and *D*, one above the other, with a gap between them to accommodate the trailer eye *E*. The connecting bolt *F* has a square head *G* and is inserted from the top. A vertical double shouldered pillar *H* is fixed to the horizontal limb of the tractor bar, immediately behind the two lugs, and the height of the top shoulder is level with the top of the head of the bolt *G*. On the reduced top end of the pillar *H* is mounted a pivoted slidable arm *J* with a socket portion at its free end, covering the head of the bolt. A compression spring and nut, as shown, keeps the arm in position. To connect the trailer coupling the free end of the arm *J* is lifted until it disengages the head *G* of the bolt, and the arm is swung aside into the position indicated by the dotted lines. The bolt is then removed and the trailer eye introduced between the two lugs, after which the bolt is inserted and the socket portion of the arm placed again over the head. To release the trailer coupling the operations are carried out in the reverse order.—*September* 21, 1955.

METALLURGY

738,510. January 6, 1953.—PROCESS FOR REMOVING MAGNESIUM FROM ALUMINIUM, American Smelting and Refining Company, 120, Broadway, New York, 5, U.S.A.

The presence of magnesium has a profound effect upon the physical properties of aluminium. For certain purposes, the magnesium must be kept below 0·10 per cent, and, in some cases, as low as 0·03 per cent, or less in the aluminium casting. The process is especially effective in treating aluminium containing less than 2·5 per cent magnesium, and it is particularly efficient in reducing the magnesium content of aluminium to below 0·1 per cent and as low as 0·03 per cent and less. The drawing represents the apparatus and process by which the invention may be practised most conveniently and economically. *A* is a reverberatory furnace of conventional design which is connected by conduit *B* to a surge tank *C*, which is provided with an exhaust outlet conduit *D*. The reverberatory furnace is provided with a burner or burners *E*, one or more charging doors *F*, plugged molten metal outlet *G*, and a suitable tube *H* for introducing chlorine into the furnace beneath the surface of the molten metal. The furnace may also be provided with a suitable pressure control means, indicated generally at *J*, for regulating the pressure of the atmosphere in the furnace. Variations in pressure



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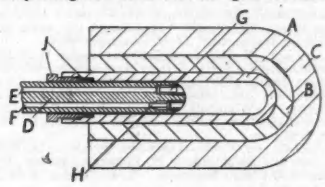
within the furnace may be transmitted to open or close the damper *K*. In operation aluminium containing magnesium is charged to the furnace through door *F* and is melted. After melting, the burners are turned off. During the melting, appreciable quantities of aluminium oxide dross form on the surface of the charge and, although it is not necessary, such dross preferably is removed after the charge is melted. Thereafter, the furnace doors and other openings through which air might leak are sealed. The atmosphere of the furnace may then be purged with a suitable inert gas, such as nitrogen or carbon monoxide. After sealing the furnace, chlorine is introduced beneath the surface of the molten metal through tube *H* and its addition is continued until the magnesium content of the aluminium has diminished to the desired value. The chlorine upon contacting the molten metal combines directly with aluminium and magnesium to form aluminium chloride and magnesium chloride respectively with the evolution of heat. The metal charge is maintained in a molten condition and generally in the range 1200 deg. to 1800 deg. Fah. preferably by controlling the rate of addition of the chlorine, preferably also, the molten pool is maintained in this range at a temperature above the melting point of magnesium chloride, which is about 1324 deg. Fah. At these temperatures, magnesium chloride exists as a liquid, and aluminium chloride as a gas since this latter compound sublimes at temperatures above 360 deg. Fah. As both of these chlorides are insoluble in the metal, the magnesium chloride collects on the surface of the metal pool and the aluminium chloride gas escapes into the atmosphere above it. Typical results are given in the specification.—*October* 12, 1955.

AIR COMPRESSORS

736,583. January 31, 1951.—HIGH-PRESSURE RECIPROCATING PUMPS AND COMPRESSORS, Imperial Chemical Industries, Ltd., Imperial Chemical House, Millbank, London, S.W.1. (*Inventor: William Reginald Dermot Manning.*)

The invention relates to pumps or compressors capable of generating pressures greater than 1000 atmospheres and its object is to reduce the danger of failure by fatigue. In the drawing a mid-sectional



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elevation of a single-stage pump or compressor comprising a piston and a cylinder is given. The means for operating and supporting the pump are not shown. The reciprocating cylinder is built up from three components, *A*, *B* and *C*, each being axially symmetrical and closed by a hemisphere. Component *B* is shrunk on to component *A* and component *C* is shrunk on to component *B*. The stationary piston *D* carries the inlet and outlet ducts *E* and *F* and the inlet and outlet non-return valves *G* and *H*, which can be of the conventional cone type. A gland and packing *J* is provided to form a seal between the piston and cylinder. The exact type of gland or valve to be used is chosen according to the working substance and the conditions of operation, e.g. pressure, temperature, running speed. In a single-stage pump of the type described and illustrated, by reason of the relatively simple shape of the cylinder head, the stresses which are likely to develop in it for a given working pressure can be calculated with considerable accuracy. Whilst it is not possible to compute accurately the stresses in the neighbourhood of the valve seats and ducts, they are predominantly compressive at these points and therefore the risk of failure due to fatigue is very greatly reduced.—*September* 14, 1955.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Tues., Dec. 20th.—LONDON NATIONAL LECTURE: Lighting Service Bureau, Savoy Hill, London, W.C.2. "The Heat Pump with reference to Domestic Installations," G. Peter Watson. 6.30 p.m.——PORTSMOUTH BRANCH: "Air Balloon," 598, Commercial Road, Mile End, Portsmouth. "Electricity in the Aircraft Industry," W. A. Pile. 7.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

Tues., Dec. 20th.—LIVERPOOL CENTRE: Liverpool Engineering Society, 9, The Temple, Dale Street, Liverpool, "Lighting in the Rayon Industry," G. E. Shepherd, 6 p.m.

INCORPORATED PLANT ENGINEERS

Tues., Dec. 20th.—S. WALES BRANCH: S. Wales Institute of Engineers, Park Place, Cardiff, "Steam and Utilisation," Films, 7.15 p.m.
Fri., Dec. 30th.—BIRMINGHAM BRANCH: Imperial Hotel, Birmingham, "Problems," 7.30 p.m.
Tues., Jan. 3rd.—LONDON BRANCH: Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2, Debate, "That our main railroads be converted to highways," 7 p.m.
Wed., Jan. 4th.—SOUTHERN BRANCH: Polygon Hotel, Southampton, "Costing and Accountancy in Relation to Plant Engineering," S. J. Clark, 7.30 p.m.

INSTITUTE OF FUEL

Wed., Jan. 4th.—Institution of Civil Engineers, Great George Street, London, S.W.1, "Some Coal Research Problems and their Industrial Implications," R. L. Brown, 5.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Tues., Dec. 20th.—85, Minories, London, E.C.3, "Nuclear Power for Commercial Vessels," Kenneth Maddocks, 5.30 p.m.
Thurs., Dec. 29th.—SCOTTISH SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Nuclear Power for Commercial Vessels," K. Maddocks, 7.30 p.m.

INSTITUTE OF NAVIGATION

To-day, Dec. 16th.—Royal Geographical Society, 1, Kensington Gore, London, S.W.7, "Handling a Ship," C. J. Wynne-Edwards, 5 p.m.

INSTITUTE OF PHYSICS

To-day, Dec. 16th.—NON-DESTRUCTIVE TESTING GROUP: 47, Belgrave Square, London, S.W.1, "Some Aspects of the Testing of Non-metallic Solids," H. Kolsky, 6.30 p.m.

INSTITUTE OF REFRIGERATION

Thurs., Jan. 5th.—Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, London, S.W.1, "Refrigeration Controls," H. H. Egginton, 5.30 p.m.

INSTITUTE OF WELDING

Wed., Jan. 4th.—N. LONDON BRANCH: Manson House, Portland Place, London, W.1, "The Brittle Fracture of Mild Steel—A Survey," Constance F. Tipper, 7 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Sat., Dec. 17th.—N.W. BRANCH: Reynolds Hall, College of Technology, Manchester, "Some Aspects of Heat Transfer in a Climbing Film Evaporator," J. M. Coulson, 3 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Dec. 20th.—WORKS CONSTRUCTION MEETING: Great George Street, London, S.W.1, "The Diversion of the Anaalong River into the Silent Valley Reservoir," C. F. Colebrook, 5.30 p.m.
Tues., Jan. 3rd.—MARITIME AND WATERWAYS MEETING: Great George Street, Westminster, London, S.W.1, "Reconstruction of the Gallions Entrance Lock at the Royal Docks of the Port of London Authority," J. A. Fisher, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Tues., Dec. 20th.—S.E. SCOTLAND SUB-CENTRE: Carlton Hotel, North Bridge, Edinburgh, "High-Speed Electronic Analogue Computing Techniques," D. M. Mackay, 7 p.m.
Mon., Jan. 2nd.—S. MIDLANDS CENTRE: James Watt Memorial Institute, Great Charles Street, Birmingham, "Methods of Teaching Technical Writing," opened by G. Parr, 6 p.m.
Tues., Jan. 3rd.—N. MIDLAND CENTRE: Central Electricity Authority, 1, Whitehall Road, Leeds, 1, "The Electrical Engineering Industry in the Post-War Economy II," G. L. E. Metz, 6.30 p.m.
Wed., Jan. 4th.—S.W. SCOTLAND SUB-CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Automatic Circuit Reclosers," G. F. Peirson, A. H. Pollard and N. Care, 7 p.m.
Thurs., Jan. 5th.—ORDINARY MEETING: Savoy Place, London, W.C.2, "Highland Water Power—The Developments of the North of Scotland Hydro-Electric Board," (the late T. Lawrie) paper to be read by an officer of the Board, 5.30 p.m.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS

Tues., Dec. 20th.—LONDON AND DISTRICT ASSOCIATE MEMBERS AND GRADUATES SECTION: Junior Institution of Engineers, Pepys House, 14, Rochester Row, London, S.W.1, Discussion, "What Fan Should I Use?" 6.30 p.m.
Thurs., Jan. 5th.—BIRMINGHAM AND DISTRICT BRANCH: Exchange and Engineering Centre, Stephenson Place, Birmingham, "Mechanical Services in the B.E.A. Hangers at London Airport," L. Copeland Watts and J. W. J. Leslie, 6.30 p.m.

INSTITUTION OF HIGHWAY ENGINEERS

To-day, Dec. 16th.—SCOTTISH BRANCH: North British Hotel, Edinburgh, "Fine Cold Asphalt," H. J. E. Carter, 7 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Dec. 16th.—JAMES CLAYTON LECTURE: 1, Birdcage Walk, London, S.W.1, "Supply, Control and Combustion of Fuel to Aero-Gas-Turbines," E. A. Watson, 5.30 p.m.
Mon., Dec. 19th.—WESTERN BRANCH: Arts Centre, Swindon, "The Development and Scope of Work Study," R. M. Currie, 7.30 p.m.——SCOTTISH A.D. CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Heat Losses in Internal Combustion Engines," A. S. Leah, 7.30 p.m.
Tues., Dec. 20th.—1, Birdcage Walk, Westminster, London, S.W.1, Informal Talk—"Engineering in Queensland," Mansergh Shaw, 5.30 p.m.
Fri., Jan. 6th.—JOINT MEETING WITH THE INSTITUTION OF ELECTRICAL ENGINEERS: 1, Birdcage Walk, Westminster, London, S.W.1, "Power Station Auxiliary Plant," G. F. Kennedy and F. J. Hutchinson, 5.30 p.m.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Tues., Jan. 3rd.—ORDINARY MEETING: Institution of Electrical Engineers, Savoy Place, London, W.C.2, "Power Plant for Telecommunications," W. J. Marshall, 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Mon., Dec. 19th.—DERBY SECTION: College of Art, Derby, "Fundamentals of Progressive Tooling," J. A. Grainger, 7 p.m.——N.E. SECTION: Neville Hall, Newcastle upon Tyne, Film Evening, 7 p.m.
Tues., Jan. 3rd.—OXFORD SECTION: Town Hall, Oxford, "Cost Accounting as an Aid to Efficient Production," H. J. Furness, 7.15 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Mon., Dec. 19th.—LONDON GRADUATES' AND STUDENTS' SECTION: 11, Upper Belgrave Street, London, S.W.1, "Engineering Problems in the Docks," G. A. Wilson, 6.30 p.m.
Wed., Dec. 21st.—YORKSHIRE BRANCH: Great Northern Hotel, Leeds, "Geophysical Methods of Exploration and Their Application to Structural Engineering Problems," J. Robertshaw, 6.30 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Dec. 16th.—Pepys House, 14, Rochester Row, London, S.W.1, Gadget Evening, 7 p.m.
Fri., Dec. 30th.—Pepys House, 14, Rochester Row, London, S.W.1, Question and Discussion Evening, 7 p.m.
Wed., Jan. 4th.—MIDLAND SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "Josiah Wedgewood—The Potter," Miss R. J. Warne, 7 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

Fri., Jan. 6th.—Engineers' Club, Albert Square, Manchester, "Polythene and its Uses," A. Renfrew, 6.45 p.m.

REINFORCED CONCRETE ASSOCIATION

Tues., Jan. 3rd.—N.W. BRANCH: College of Technology, Sackville Street, Manchester, "Selection and Grading of Aggregates for Various Types of Concrete Works," J. D. McIntosh, 6.45 p.m.

ROYAL AERONAUTICAL SOCIETY

To-day, Dec. 16th.—SECTION LECTURE: Library, 4, Hamilton Place, London, W.1, "Airships of To-day," Lord Ventry, 7 p.m.
Tues., Dec. 20th.—SECTION LECTURE: 4, Hamilton Place, London, W.1, "Recent Advances in Aircraft Adhesives," N. A. de Bruyne, 7 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Mon., Jan. 2nd.—ORDINARY GENERAL MEETING: 12, Great George Street, Westminster, London, S.W.1, "The Continuous Revision of Ordnance Survey Maps and Plans," A. H. Dowson and M. O. Collins, 5.30 p.m.

WEST OF SCOTLAND IRON AND STEEL INSTITUTE

To-day, Dec. 16th.—Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Some Aspects of Blast-Furnace Operation," E. H. Baldwin, 6.45 p.m.

Catalogues and Brochures

QUALTERS AND SMITH BROTHERS, Ltd., Old Foundry, Barnsley.—Folder giving details of 6in, two-speed "Sawmaster" heavy-duty hacksaw.

EVERED AND CO., Ltd., Surrey Works, Smethwick, 40, Staffordshire.—Brochure describing "Everex" polythene tube with details of its applications.

THE MORGAN CRUCIBLE COMPANY, Ltd., Battersea Church Road, London, S.W.11.—Illustrated leaflet dealing with silicon carbide refractories.

HANCOCK AND CO. (ENGINEERS), Ltd., Progress Way, Croydon.—Illustrated brochure describing "Hancomatic" oxygen cutting and profiling machines.

HIGH DUTY ALLOYS, Ltd., Slough, Bucks.—Booklet entitled "Aircraft Stampings," illustrating some typical Hiduminium forgings and stampings.

THE WALTERISATION COMPANY, Ltd., Purley Way, Croydon.—Leaflet giving details of a phosphating process for increasing the corrosion resistance of iron and steel.

FEL ELECTRIC, Ltd., 41, Sidney Street, Sheffield, 1.—Leaflet describing "Feltec" crack detection inks for the detection of cracks and flaws in magnetisable metals.

RANSOMES AND RAPIER, Ltd., Waterside Works, Ipswich.—Publications Nos. 1/494 and 495, describing standard mobile cranes for loads up to 3 tons, 6 tons and 7½ tons.

MEASURING INSTRUMENTS (PULLIN), Ltd., Electrin Works, Winchester Street, Acton, London, W.3.—Pamphlet describing a range of miniature electrical measuring instruments.

INTERNATIONAL COMBUSTION, Ltd., 19, Woburn Place, London, W.C.1.—Publication No. M559, entitled "Ash Handling," giving details of plant to handle ash dust and grits from boiler plants.

FRY'S DIECASTINGS, Ltd., Midland Works, Brierley Hill Road, Wordsley, near Stourbridge.—Leaflet giving details of the electroplating, chemical treatments, painting or enamelling of aluminium-bronze.

THE CAPE ASBESTOS COMPANY, Ltd., 114-116, Park Street, London, W.1.—Brochure describing the raw material and essentials for ideal insulation showing examples of various preformed products, lagging materials and insulation accessories. Details are given of a long fibre rock wool and Vermiculite, and this is followed by a technical section containing formulæ and calculations, tabulated data for thermal insulation materials, together with reference and conversion tables.

WARERITE, Ltd., Ware, Herts.—Brochure giving information concerning "Novopan" fire-retarding divisions for ships. "Novopan" is stated to be available in standard sheets up to a maximum of 8ft by 3ft and in thickness ranging from 13mm to 40mm, and in two forms, namely, "Novopan B," which consists of a core of synthetic resin-bonded wood fibres, two layers of asbestos and surfaced with cross-banded hardwood veneers, and "Novopan FX," which is similar, but without the asbestos.

ISOPAD, Ltd., 30-32, Rosemont Road, London, N.W.3.—Illustrated leaflet describing "Isojackets," a combined electric heating and lagging unit for columns, pipes and cylindrical vessels of all dimensions. The jackets combine a heating panel backed by glass wool lagging, enclosed in cylindrical sheet metal casings. For use in flameproof areas the heating element is metal sheathed and mineral insulated. Standard "Isojackets" are suitable for temperatures up to 400 deg. Cent. (750 deg. Fah.).

BRITISH WELDING RESEARCH ASSOCIATION, 29, Park Crescent, London, W.1.—"The Principles of Argon-Arc Welding Aluminium," prepared by P. T. Houldcroft, is the first of a series of six booklets which will form a complete handbook on the argon-arc welding of aluminium alloys. Other booklets in this series will cover "Electrical Characteristics and Equipment," "Metallurgical Considerations," "Design Applications and Costs," "Techniques and Procedures," and "Inspection and Testing."

Launches and Trial Trips

REDCAR, ore carrier; built by Smith's Dock Company, Ltd., for the Yorkshire Shipping Company, Ltd.; length overall 505ft, length between perpendiculars 480ft, breadth moulded 68ft 9in, depth moulded 36ft 3in, deadweight 15,200 tons on 28ft 11in draught, service speed 11¼ knots; four main cargo holds with wing tanks at sides, one 3-ton and two 5-ton derricks, steam deck machinery; two 75kW steam-driven generators, one 75kW diesel-driven generator; two Scotch marine boilers; Hawthorn-Doxford opposed piston, two-stroke, oil engine, four cylinders, 670mm diameter by 2320mm combined stroke, 4450 b.h.p. at 115 r.p.m.—Launch, October 31st.

CRYSTAL GEM, bulk sugar carrier; built by Hawthorn Leslie (Shipbuilders), Ltd., for the Sugar Line, Ltd.; length between perpendiculars 430ft, breadth moulded 61ft, depth moulded to upper deck 37ft 3in, deadweight 9750 tons, draught 24ft 6in, service speed 12 knots; five holds with wing compartments, steam deck machinery; two 75kW diesel-driven generators, one 20kW steam-driven generator; one composite exhaust gas-fired boiler, one cylindrical boiler; Hawthorn-Doxford diaphragm oil engine, four cylinders, 600mm diameter by 2320mm combined stroke, 3300 b.h.p. at 108 r.p.m.—Launch, November 1st.

BORDER SENTINEL, oil tanker; built at the Neptune works of Swan, Hunter and Wigham Richardson, Ltd., for The Lowland Tanker Company, Ltd.; length overall 547ft, length between perpendiculars 515ft, breadth moulded 69ft 6in, depth moulded 37ft 6in, deadweight 16,000 tons on 30ft summer draught; twenty-seven cargo oil compartments, two cargo oil pump rooms, four 500 tons per hour cargo pumps, steam smothering system, Butterworth tank cleaning system, compressed air salvage installation, steam deck machinery; two 150kW diesel-driven generators, one 75kW steam-driven generator; two Scotch boilers; Swan, Hunter-Doxford oil engine, arranged to burn boiler fuel, six cylinders, 670mm diameter by 2320mm combined stroke, 6400 b.h.p. at 115 r.p.m.; trial speed 14¾ knots.—Trial, November 3rd.

SAN FORTUNATO, oil tanker; built by Cammell, Laird and Co. (Shipbuilders and Engineers), Ltd., for the Eagle Tanker Company, Ltd.; length between perpendiculars 530ft, breadth moulded 69ft 3in, depth moulded 39ft, summer draught 29ft 8in, deadweight 18,000 tons; thirty-three oil cargo compartments, one main cargo pump room, two 550kW turbo alternators, one 200kW diesel-driven generator; one set of double reduction geared turbines of 8250 s.h.p. take steam at 500 lb per square inch gauge and 800 deg. Fah. from two Babcock and Wilcox water-tube boilers. Launch, November 15th.

SOUTHERN PRINCE, cargo ship; built at the Govan Shipyard of Harland and Wolff, Ltd., for the Prince Line, Ltd.; length between perpendiculars 435ft, breadth moulded 61ft, depth moulded to shelter deck 38ft 6in, deadweight 10,000 tons on 27ft 6in draught; five holds, one 50-ton, four 10-ton and twelve 5-ton derricks, steam deck machinery, three 50kW steam-driven generators; Harland and Wolff single-acting, two-cycle, opposed piston oil engine, five cylinders 750mm diameter by 2000mm combined stroke, 110 r.p.m.. Launch, November 16th.

ELIN KNUDSEN, oil tanker; built by Harland and Wolff, Ltd., at Belfast for Knut Knutsen, Norway; length overall 665ft, length between perpendiculars 630ft, breadth moulded 85ft 6in, depth moulded 46ft 8in, deadweight 32,000 tons on 35ft summer draught; thirty oil cargo compartments, one main cargo pump room, three 350kW diesel-driven generators, one set of double-reduction geared turbines, 12,500 s.h.p. at 112 propeller r.p.m., two Babcock and Wilcox integral furnace water-tube boilers supply steam at 450 lb per square inch gauge and 750 deg. Fah. Launch, November 17th.

RED HACKLE, trawler; built by John Lewis and Sons, Ltd., for the Iago Steam Trawler Company, Ltd.; length between perpendiculars 135ft, breadth 26ft 6in, depth 13ft 3in, gross tonnage 402 tons, fish room 9300 cubic feet, electric deck machinery and an electric trawl winch having a capacity of 1000 fathoms of 2¾in warp; British Polar diesel engine, five cylinders, 800 b.h.p. at 250 r.p.m. Trial, November 22nd.

H.M.S. LLANDAFF, air direction frigate; built by Hawthorn Leslie (Shipbuilders), Ltd.; length overall 340ft, beam 40ft, main armament two 4·5in guns, Admiralty standard range diesel engines. Launch, November 30th.

H.M.S. HARDY, "Blackwood" class anti-submarine frigate; built by Yarrow and Co., Ltd.; length overall 310ft, length between perpendiculars 300ft, breadth extreme 33ft, complement 7 officers and 104 men; armament three 40mm Bofors guns and two three-barrelled anti-submarine mortars, two twin torpedo tubes, all welded construction, electrical system 440V a.c., three-phase, 60 c/s, one set of geared turbines designed by the English Electric Company, Ltd. Acceptance into service, December 15th.